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THE GEOGRAPHIC PATTERN AND TRAFFIC PROBLEMS OF WARREN, OHIO[1]

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Warren is located in the south-central portion of Trumbull County in northeastern Ohio. By highway, it is 52 miles southeast of Cleveland, 14 miles northwest of Youngstown, 86 miles northwest of Pittsburgh, and 41 miles east of Akron (fig. 1). It lies in the path of US Route 422, and State Routes 5, 45, 82, and 169 (fig. 2).

THE GEOGRAPHIC PATTERN OF WARREN

The city occupies an area of 5582.4 acres, or about 8.7 square miles. Its plat is rectangular with the east-west distance measuring almost 4 miles and the north-south span equalling slightly less than 3 miles. It is bisected by the southeastward flowing Mahoning River (fig. 2).

The Transportation Pattern

The arterial highways. The street pattern of Warren was originally intended to resemble that of a New England town, with a square or rectangular grid, but the development of the city witnessed the introduction of several diagonal arterial highways, namely, Niles and Youngstown roads to the southeast, Mahoning Avenue to the northwest and north, Parkman Road to the northwest, and Elm Road to the northeast (fig. 2). However, a remnant of the New England town pattern survives in the commercial core area. There is a decided lack of arterial routes circumventing the commercial core; hence, the core has become the focus for the traffic of the city.

The Railroads. Significant aspects of the relationship of the railroad pattern and the traffic problems are discussed elsewhere in this paper. It may be noted here that the railroads passing through Warren are the Erie (Mahoning Division and Main Line), the Baltimore and Ohio (Painesville Division and Pittsburgh and Wheeling Division), the Pennsylvania (Youngstown and Ashtabula Division), and the New York Central (which runs through Warren on the rails of the Mahoning Division of the Erie Railroad).

The Residential Pattern

The residential parts of Warren surround the commercial core and are located chiefly on the east side of the Mahoning River. Approximately 70 percent of Warren's 50,000 residents live on the east side of the river, 30 percent residing north of East Market Street, and the remaining 40 percent living south of it. On

[1]This manuscript is a condensation of thesis submitted to the Department of Geography, Kent State University, in partial fulfillment of the requirements for the Master of Arts degree. Author's present address: R. D. No. 1, East Orwell, Ohio.

the west side of the river, 14 percent live north of West Market Street, while 16 percent live south of it (fig. 2).

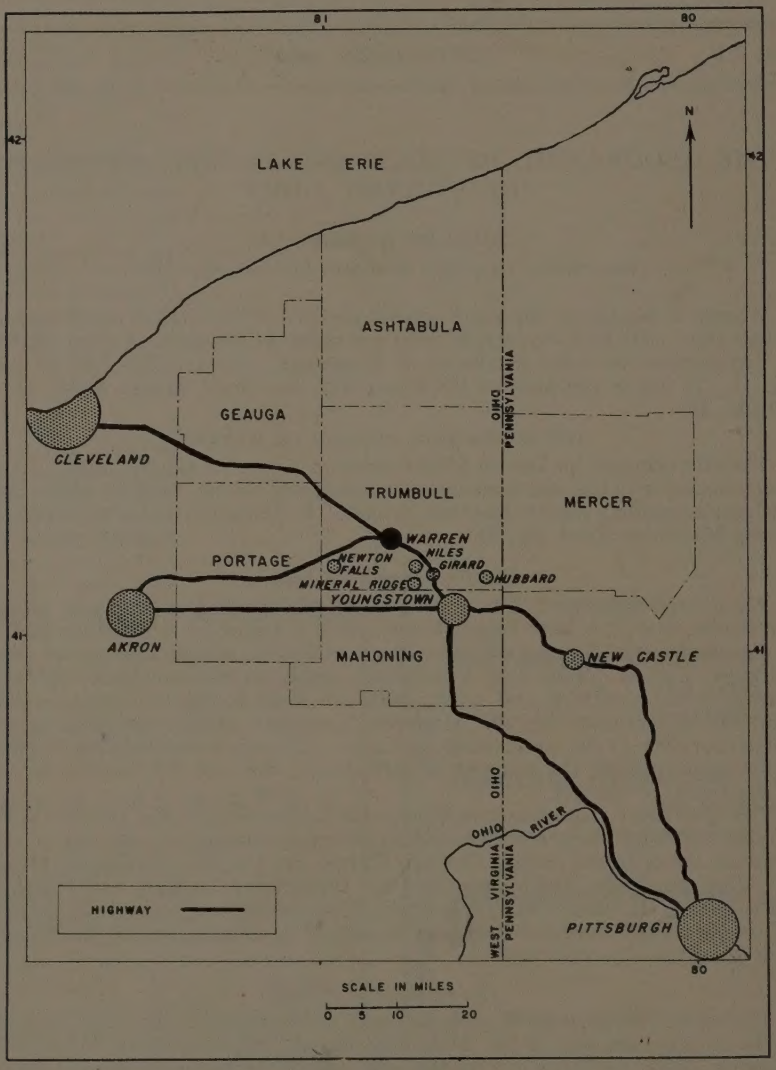

FIGURE 1. Location of Warren, Ohio.

The Commercial Pattern

The commercial core, consisting of about eight blocks, is located slightly to the southwest of the center of the city. The corner of North Park Avenue and East Market Street (the most important street of the core) is the focal point and the approximate center of the core (fig. 3).

The Industrial Pattern

Three major and three minor industrial areas may be recognized. A major area is located one and one-half miles north of the corporate limits of Warren on Mahoning Avenue Route 45 (fig. 2). A second major area is situated in southern Warren and contains plants of Warren's largest industry, the Republic Steel Corporation (fig. 2). The third major area occupies the property in an attenuated fashion along the Erie (Main Line) Railroad in northern and northeastern Warren proceding eastward from the intersection of the Erie and B. and O. railroads (fig. 2).

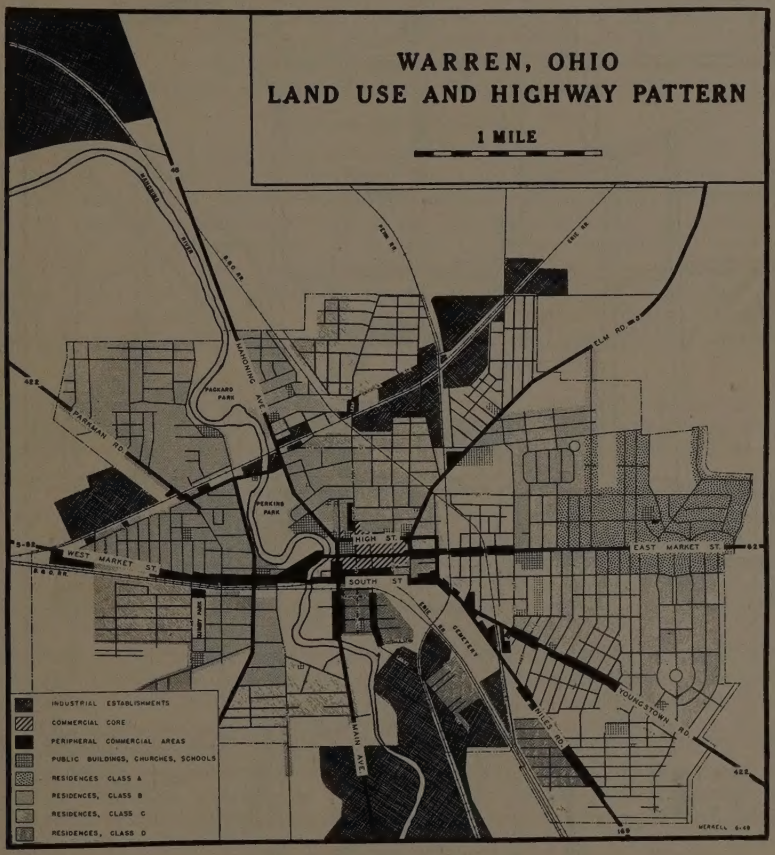

FIGURE 2. Land use and highway pattern of Warren, Ohio.

The third major area is continued to the north and northeast in the triangle between the Pennsylvania and the Erie railroads, an area which lies outside the city limits (fig. 2).

A minor area of industrial activity is found along the Erie Railroad near the Mahoning River in northern Warren (fig. 2). A second minor area is located in western Warren along the Erie Railroad, while a third area is situated along West Market Street (fig. 2).

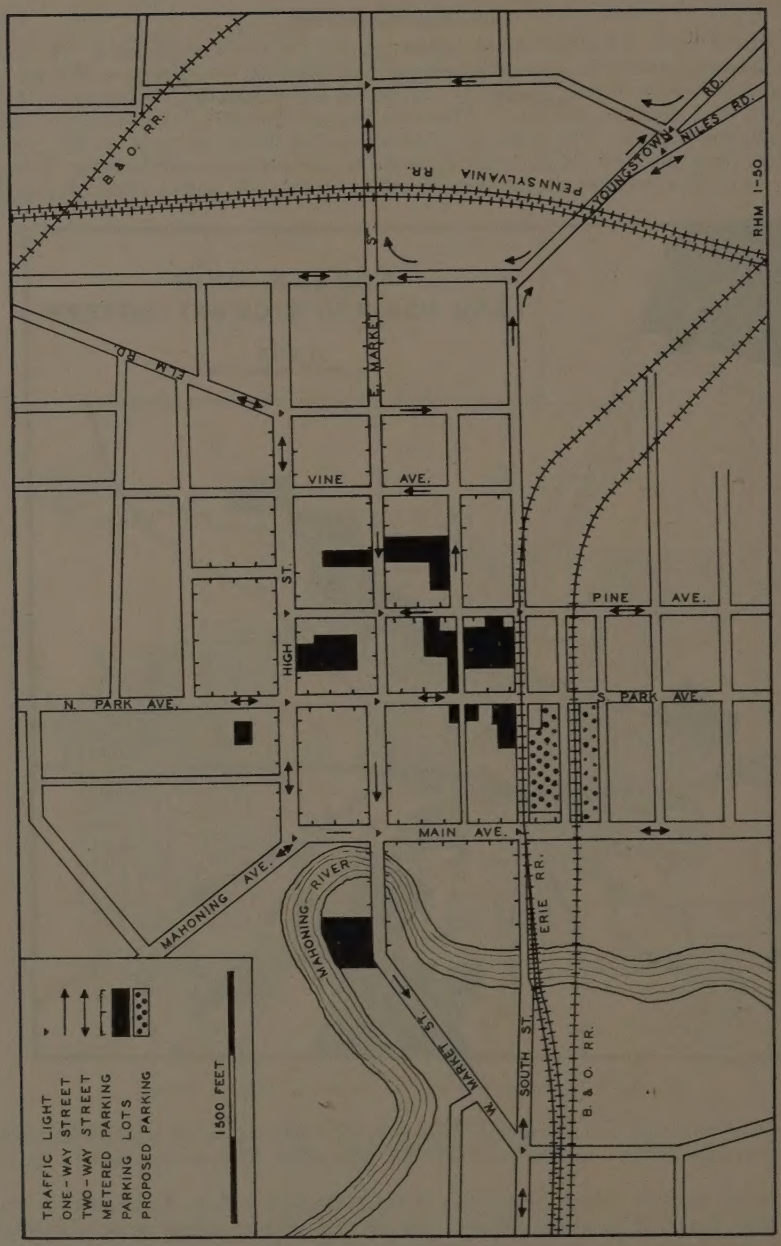

FIGURE 3. Commercial core and proposed one-way street system of Warren, Ohio

Summary

The industries of Warren are not concentrated in one portion of the city, but rather are localized in five dispersed areas. Due to the lack of alternate routes, the commercial core, which is located almost in the center of the city, is the focus for the traffic of the city.

THE FUNCTIONS OF WARREN

The Industrial Function

Warren is primarily an industrial city with 45 major industries which employ 22,000 people, or about two-fifths of Warren's total population. The city contains a number of diversified industries, although the primary metal industries employ 37 percent of all industrial workers, and the electrical industries employ 25 percent.

The Commercial Function

The Warren Retail Merchants Association has estimated that the inhabitants of Warren are responsible for 55 to 70 percent of the trade in the commercial core area, and the Warren Chamber of Commerce has estimated that 97 percent of Trumbull County's residents are served by Warren commercial establishments. With relation to the trading area of Warren, the writer conducted a survey of automobiles parked in the commercial core area of Warren on a weekday and a Saturday and found that 23 and 35 percent, respectively, of the sampled automobiles were licensed outside of Warren. Seventy percent of the out-of-town automobiles were licensed in communities within a fifteen mile radius of Warren.

The Residential Function

The residential function of Warren is becoming increasingly important. In 1940, 42,837 inhabitants of Warren occupied 11,342 dwelling units,[2] and by the end of 1948, 50,000 people were occupying approximately 15,000 dwelling units.

The Transportation Function

Intra-city transportation. Municipal bus service is supplied over nine regular routes. Thirty buses cover a total of 68,500 miles and carry an average of 421,000 passengers each month.[3] Two taxicab companies operate 30 cabs and transport a monthly average of 40,000 passengers. Two Railway Express agencies and 15 motor freight lines provide for the transportation of freight to points within Warren.

Inter-city transportation. Passenger transportation to other cities is offered by the Erie Railroad, and by numerous bus companies. Freight transportation offered by all railroads and by motor freight lines. Regular bus service to many points surrounding Warren is offered, bus service between Warren and Youngstown is most frequent. Warren is also a stopping point for many interstate buses, especially those traveling between Cleveland and Pittsburgh.

Private passenger automobiles. In 1948, over 16,000 motor vehicles were registered in Warren, of which about 13,000 were private passenger automobiles.[4]

The Recreational Function

There are three public parks in Warren; Packard and Perkins, the larger parks, are located along the Mahoning River north of Market Street, while Quimby, the smaller one, is located in southwest Warren (fig. 2).

Warren has five motion picture theaters, all of which are located in the commercial core.

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[2]United States Bureau of the Census, *Sixteenth Census of the United States, 1940: Housing*, Vol. I, Part 2, (Washington: Gov't Printing Office, 1943), p. 219.

[3]The Warren Transportation Company.

[4]Bureau of Motor Vehicles, Columbus, Ohio.

Taverns, cafes, night clubs, and other similar amusement or recreational establishments are well distributed throughout the city, although Market Street contains more of these establishments than any other single street.

Summary

Warren is primarily industrial in function, but it is also important as a service center for a relatively large trading area. It has adequate municipal transportation facilities which are well integrated with other transportation systems. Its recreational areas and establishments are situated on or near arterial highways.

THE TRAFFIC PROBLEMS OF WARREN

The Geographic Bases of the Problems

One of the basic factors in the creation of an urban traffic problem is that of residents and their distribution. The traffic problems of Warren are caused by the movements of a large percentage of the community, plus the movements of those people who are coming to, going from, or passing through it.

Four types of human movements or traffic flows may be recognized. The first is made by those who live within Warren and move from their homes to another point within the city and, after a lapse of time, return. The second type involves the people living within the city who move to a point outside and return. The third type involves those living outside the city who commute to the city and return. The fourth type of flow is produced by the transient who is merely passing through the city. The direction of the four types of human movements or traffic flows may be affected by several factors.

The location of industry. The location of the industry with which an individual is affiliated with relation to the location of his home determines, to a large extent, the direction and route of his movement to and from that industry.

The location of the commercial core. The central location of the commercial core brings about a convergence of traffic flows originating in all parts of the city and out-lying areas.

The distribution of recreational facilities. The recreational facilities of Warren, which include the public parks, motion picture theaters, and drinking places, have a definite influence upon the traffic flow. The parks attract large numbers of people in the summer months, while the movies of the commercial core account for much of the traffic flow during evenings of the cooler months.

The distribution of various classes of people. The location of various classes of people within the city affects, to a minor degree, the traffic flow patterns of the city, especially in the evening and during the weekend. Persons of similar economic circumstances and cultural backgrounds are more likely to move in the same social circle. A person living near Youngstown Road in the Class B type of residence (fig. 2) is more likely to have friends in other Class B portions of the city than in the adjacent Class A or C sections. Small traffic flows are thereby created among similar residential areas.

The location of schools and churches. These have a profound effect upon the volume and direction of the traffic flows. The solitary public high school on Elm Road in northeast Warren, and the parochial school near High Street and Elm Road (fig. 2) draw upon the whole of Warren for their student bodies, and greatly affect the early morning and mid-afternoon traffic flow patterns. Churches are well distributed throughout the city, but the largest are located in the commercial core area. The heavy concentration of large churches in this area attracts large numbers of people and thereby affects greatly the Sunday morning traffic volume and flow pattern.

The location, number, and types of arterial highways. This factor largely determines the direction and the density of the city traffic flows. The insufficient

number of alternate routes places an undue flow load upon the available highways. The convergence of arterial highways upon the commercial core practically predetermines the traffic flow pattern. Furthermore, the width and condition of these highways largely determines the speed and density of moving traffic.

An Analysis of the Vehicular Traffic of Warren

The bulk of the data for the analysis was obtained by taking traffic counts at all entrances to the city on major highways, except Route 45 South, and at two locations within Warren. An accurate count of vehicular traffic was recorded from 9 a.m. to 6 p.m. at city entrances for all days excepting Sunday, and from 7 a.m. to 6 p.m. on the same days at two locations within the city.

Daily and hourly differentials of traffic entering and leaving Warren. During the week the hour of heaviest traffic volume was between 4 and 5 p.m., which was due mainly to the fact that most industrial plants changed shifts at 4 p.m. On Saturday, the greatest number of vehicles entered Warren from 12 to 1 p.m. and departed from 2 to 3 p.m. The Saturday peak hours are largely caused by shoppers since few industrial plants operate more than a five-day week. The Saturday traffic volume was from 2 to 33 percent greater than the average weekday volume, a fact which indicates the importance of Warren as a shopping center for the surrounding population.

Classes of vehicles entering and leaving Warren. Of all vehicles, private passenger automobiles accounted for 78 percent; tractor-trailers, almost 4 percent; heavy trucks, 7 percent; light trucks, slightly over 8 percent; all buses, 1 percent; and taxicabs and other vehicles, slightly over 1 percent. All trucks represented slightly less than 20 percent of all vehicles.

Daily and hourly differentials of traffic within Warren. On West Market Street at the bridge over the Mahoning River (fig. 3), the Saturday volume was 5 to 15 percent greater than the weekday volume, while on Youngstown Road at the Pennsylvania Railroad crossing (fig. 3), the average weekday volume was 8 percent higher than the Saturday volume. The highest volumes were recorded on Monday and Saturday at the former location, and on Monday and Friday at the latter.

The peak hours of eastbound traffic at the Market Street location were from 10 to 11 a.m. on Monday and Saturday, 3 to 4 p.m. on Tuesday, 3 to 5 p.m. on Wednesday, and 4 to 5 p.m. on Thursday and Friday, while the westbound peak hours were from 4 to 5 p.m. on Monday, Tuesday, Thursday and Friday, from 3 to 4 p.m. on Wednesday, and from 12 to 1 p.m. on Saturday. The eastbound peak hours on Youngstown Road were from 4 to 5 p.m. on weekdays and from 2 to 3 p.m. on Saturday, while the westbound peak hours were from 4 to 5 p.m. on Monday and Wednesday, 9 to 10 a.m. on Tuesday, 12 to 1 p.m. on Thursday and Saturday, and from 2 to 3 p.m. on Friday.

Classes of vehicles within Warren. All private passenger automobiles comprised 80 percent of the vehicular traffic movements at the combined locations during the weekdays, and 82 percent on Saturday. All trucks accounted for almost 16 percent during the weekdays and almost 14 percent on Saturday. All buses represented 1 percent. Taxicabs and other vehicles represented 2 percent on weekdays and almost 3 percent on Saturday.

Problems Resulting from the Mixture of Different Classes of Traffic

In the commercial core area, one of every six vehicles is a truck, and one of every twenty vehicles is a tractor-trailer. These cumbersome, slow-moving vehicles have decreased the speed of the traffic flow, created a hazard for pedestrians at intersections where turning movements occur, and increased the possibility of accidents when faster moving vehicles attempt to pass the slower moving trucks, and are a major factor in the problem of traffic congestion.

Traffic Congestion

Congestion of traffic is evident during peak hours in most parts of the commercial core area. Congestion on East Market Street between Vine and Main avenues is largely due to five factors: (1) it is the only east-west arterial highway; (2) East Market Street between North Park and Pine avenues is 13 feet narrower than the next block west, and seven feet narrower than the next block east, thus effecting a channelling of traffic into a narrow bottleneck; (3) it is designated as Route 5–82 and carries a rather heavy volume of through traffic; (4) classes of traffic are intermixed; and (5) traffic lights are not adjusted for maximum vehicular flow.

Congestion on South Street (fig. 4) may be attributed to the following factors: (1) only two lanes are available for moving traffic between Pine and Main avenues;

FIGURE 4. Traffic congestion on South Street between Main Avenue and West Market Street. Traffic backlogs like this one are common occurrences on South Street.

(2) turning movements from South Street cause considerable backlogs of traffic to form; (3) South Street attracts much traffic which attempts to avoid congestion on East Market Street; and (4) traffic light stop-and-go periods are not adjusted for the traffic volume.

The dismissal of industrial employees within the same brief period of time is a major cause of traffic congestion in all parts of Warren.

The South Street Problem

Through the center of South Street between Main and Pine avenues run the tracks of the Erie Railroad. The north side is used for moving traffic only, while the south side is used only for parking (fig. 5).

Periodically, passenger and freight trains travel the rails through the center of the street (fig. 5) and traffic hazards are thereby created. Although the location of the railroad increases the element of danger to moving automobiles and pedes-

trians, it imposes no other serious traffic problems other than congestion at intersections due to the halting of traffic whenever a train approaches.

Other Traffic Problems

Traffic accidents. Traffic accidents are decreasing in number whereas the number of motor vehicles is increasing. In 1940, there were 13,526 motor vehicles registered in Warren and a total of 978 traffic accidents. In 1947, over 15,000 motor vehicles were registered and 675 traffic accidents occurred. The number of vehicles had increased more than 10 percent, but the number of traffic accidents had decreased by 31 percent. Traffic accidents in 1948 had decreased by 24 percent. In 1947, the commercial core area accounted for slightly over one-third of all

FIGURE 5. The tracks in South Street between Main and Pine Avenues. Note the approaching train.

traffic accidents. Almost one-half of all accidents occurred on Market Street, and about one-eighth occurred on South Street. The number of traffic accidents has been reduced by the lowering of the speed limits on arterial highways from 35 MPH to 25 MPH, by stricter supervision and enforcement, and by educational campaigns.

The parking problem. Almost every city has a parking problem, and Warren is no exception. Every day thousands of automobiles enter the commercial core area and attempt to find parking space. The task is often difficult, especially on Saturday, and frequently automobiles must be parked a considerable distance from the commercial core.

Parallel free parking is permitted on most streets except in the commercial core area where 542 parking meters have been installed. Nine parking lots, accommodating about 700 automobiles, are distributed throughout the core area (fig. 3).

Summary and Conclusions

Among the most serious of the traffic problems is the congestion of traffic which is caused by many factors, including the lack of alternate routes, the mixture of different classes of traffic, the dismissal of industrial employees from all plants at approximately the same time, and inefficient traffic signal timing. If this problem were solved, or at least alleviated, other associated problems would become less serious.

The writer's analysis of the traffic problems has led him to believe that the following proposals would go far toward improving the city traffic situation.

Approximately 11 percent of the vehicular traffic entering and leaving the city is composed of tractor-trailers and heavy trucks. An assumption might be made that over one-half of these trucks are through trucks, i.e., their destination is beyond Warren and not in it. If this assumption is approximately correct, a rerouting of through trucks around the city would decrease traffic congestion by considerably more than 6 or 7 percent, which is the percentage of total vehicles to be rerouted. The routes encircling the city would involve a greater driving distance, but time lost because of distance would nearly equal time lost in Warren due to congestion.

The second proposal calls for a series of one-way streets (fig. 3). This plan would certainly eliminate much of the congestion in the commercial core area, and in addition, would allow traffic to pass through Warren at a much faster rate. Third, the writer recommends that major industrial plants change shifts alternately with one hour intervals. Under this plan, industrial workers from the major plants would not be on the streets at the same time; hence, much congestion would be avoided. Fourth, part of a slum area south of South Street might be razed and parking facilities constructed (fig. 3). Commercial core parallel parking should be prohibited. A fifth proposal calls for the installation of a centrally controlled traffic light system with lights set at a progressive rate, i.e., lights that change to green progressively as traffic moves along at a given rate of speed. This would allow traffic to move at a uniform speed through the city at almost twice its present rate.

Sixth, the narrow block on East Market Street should be widened to correspond as closely as possible to the general width of the street. This would help eliminate congestion in this and preceding blocks. The seventh proposal would result in police supervision at hazardous locations during peak hours. At present, police supervision is evident at two intersections in the commercial core from 10 a.m. to 12 p.m. and from 3 to 5 p.m., but these hours are not complete peak hours. Peak hours have been established by this study as being from 7 to 9 a.m. and 3 to 6 p.m. on weekdays, and from 10 a.m. to 3 p.m. on Saturday.

The eighth proposal would result in the widening of South Street, particularly the portion which contains the railroad, so that heavy volumes of traffic will be able to move unimpeded along the street at a rapid rate. The ninth and final proposal is that a press and radio campaign be inaugurated to persuade the public to use bus transportation more frequently rather than their automobiles. The results of the campaign would probably decrease traffic congestion by a small percentage.

Instructions for preparation of manuscripts and illustrations for publication in the Ohio Journal of Science may be obtained by writing to the Editor.

THE BOX BUTTE TABLELAND

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The Box Butte Tableland (fig. 1), a physiographic subdivision of the High Plains Region of the United States, is a rather flat, undissected upland of few streams and scant rainfall. The area received its name from a prominent butte-like landmark located in the northeastern part of Box Butte County, Nebraska (fig. 2).

FIGURE 1. Location map of the Box Butte Tableland.

Box Butte offers mute evidence of a former, much higher level of the High Plains Region, now greatly reduced through the seemingly endless action of wind and water. The upland (fig. 3) is typical of the fluvial remnants of a vast detrital fan which, in geologic ages now long past, was spread out to the eastward from the base of the Rocky Mountains by widely shifting but heavily laden depositing streams (Johnson, 1902).

The tableland presents three distinguishing characteristics: (1) a comparatively flat plains country; (2) a practically treeless but grass-covered expanse; and (3) an area in which rainfall is usually insufficient for tillage agriculture common to regions of humid climate. Relatively speaking, the country is high, dry, and healthful. There are broad plains and scattered buttes; few streams; tornadoes, cloudbursts, dust storms, hot winds, cold waves, and blizzards; short nutritious

grasses that in dry seasons are often destroyed by devastating fires; bellowing cattle and bleating sheep; barbed wire fencing; whirling windmills; isolated farm- and ranchsteads; and small towns so widely scattered that the distances between them tend to discourage the normal social development of a people.

FIGURE 2. A view from the southwest of Box Butte for which the entire tableland, as well as a county and creek, are named. The original cap rock was removed by early settlers for foundation stones in houses and barns.

LOCATION AND EXTENT

The Box Butte Tableland extends from the rim overlooking the North Platte Valley (fig. 4) northward to the deeply dissected *breaks* of the Niobrara Valley, and from the grass-covered Sandhill Region of north-central Nebraska westward to the Hartville Uplift in east-central Wyoming (fig. 5). Well-marked by physiographic features characteristic of a semiarid country, this tabular upland consists of approximately 2,820 square miles, about 2,000 of which are in the state of Nebraska.

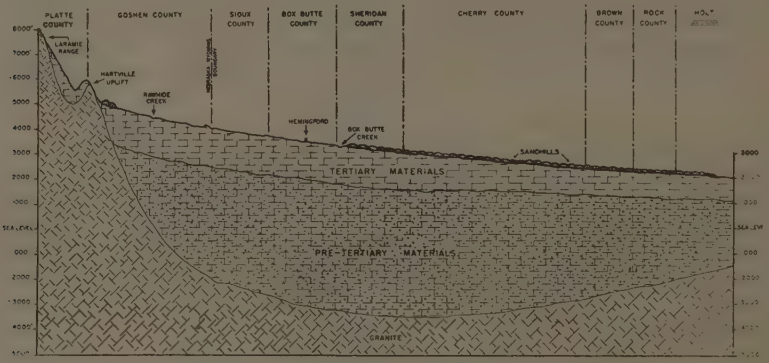

FIGURE 3. Geologic cross section of eastern Wyoming and western Nebraska. Adapted from Condra, Darton, Lugn, and others.

TOPOGRAPHY AND STRUCTURE

Contrary to widespread belief, the landscape is not one of wearisome sameness. In addition to the large stretches of level, monotonous plains country, it is marked by several lonely buttes; by low hills and ridges; by small, widely separated intermittent drainage ways and streams, fringed occasionally by clumps of cottonwoods and willows; and by numerous but widely scattered basin-like depressions believed to have been formed by wind erosion of exposed silty and sandy beds of the Tertiary (Lugn, 1935). The basins have an elongation from northwest to southeast and are often occupied by ephemeral ponds. A thin layer of hardpan occurs within a few inches of the surface of the depressions, sealing their bottoms to such an extent that precipitation disappears almost entirely through evaporation, little by seepage. The drainage ways and streams have for the most part a northeast, east, or southeast trend, thus reflecting the general slope of the tableland.

FIGURE 4. Southern rim of the Box Butte Tableland overlooking the valley of the North Platte River in the vicinity of Bridgeport, Nebraska. The escarpment, rising from 500 to 1000 feet above the valley's bottom lands, presents a distinct barrier to transportation.

The area follows the normal inclination of the High Plains Region, sloping from west to east. Altitude and declivity are due mainly to the geologic structure and climatic conditions experienced in the past. In addition to its easterly slope, there is a slight tilt from northwest to southeast, with the highest altitude of slightly more than 5,000 feet found in the northwestern corner of the tableland and the lowest, approximately 3,800 feet, in the southeastern part.

Structure is comparatively simple. Below the mantlerock and exposed in many places are well-defined sedimentary formations of fluviatile origin which lie in a nearly horizontal position (fig. 6). These Tertiary deposits consist principally of poorly cemented sandstones and conglomerates laid down by heavily laden Rocky Mountain streams; extensive beds of sandy clays and shales are also present. One of the more resistant formations, the Arikaree, serves as a cap rock for most of the area and is largely responsible for the broad, nearly flat or gently rolling tabular uplands (Darton, 1903, 1905). The Arikaree is comprised largely of thick beds (700–800 feet) of fine, poorly cemented sand separated by thinner layers of hard, fine-grained, dark-gray sandstones which vary greatly in hardness and are characterized by extensive pipy concretions. In examining an outcrop of the Arikaree, there is usually found a rather sharp face and well-developed talus slope.

The more sandy materials can be broken without difficulty and the pieces quickly disintegrated when rubbed between the hands, thus showing the weakness of cementation. Some of the sandy beds are argillaceous with the colors uniformly light gray.

In many localities this particular type of bedrock gives rise to steep walled canyons, especially noticeable along the southern edge of the Box Butte Tableland, and in the lower course of Dry Creek, an intermittent tributary of the Niobrara River which has deeply dissected the northern edge of the upland in Box Butte County. The Arikaree not only constitutes the crest of the rim overlooking the North Platte Valley but extends, as previously pointed out, throughout most of the tableland, thereby forming so to speak, a pronounced platform.

FIGURE 5. Eastern front of the Hartville Uplift, with the course of Rawhide Creek marked by a narrow line of brush and small trees. The ranchstead in the right background occupies a choice site but is confronted by problems which arise from isolation.

In regard to the conglomerate deposits it appears that streams first carved out valleys in the Tertiary beds and then at a later period filled them with coarse sands and gravels, the latter often being crystalline in origin. With the passage of time these deposits became cemented through the presence of iron and lime, thereby forming the existing conglomerates. Tea Kettle Butte, located north of Bridgeport, Nebraska, and adjacent to the southward-facing edge of the Box Butte Tableland, offers excellent specimens of these conglomerate materials.

A somewhat unique feature of the Box Butte Tableland is the presence of several dunesand tracts. Dunes occur in southern Box Butte and Sioux counties, Nebraska, with occasional scatterings in west-central Box Butte, across central Sioux County, and into Goshen County, Wyoming. The dune areas in the central part of Sioux County can be accounted for by exposure to the elements of the sandier layers of the Arikaree. The intermittent belt of sand hills extending along the southern margins

of the Box Butte Tableland cannot be explained so readily. This accumulation of sand may have resulted from eroding of the Arikaree, but most likely it is from the North Platte River bed, where the winds have picked up the dry sand during periods of low water and deposited it upon the tableland's edge. The dunes on the

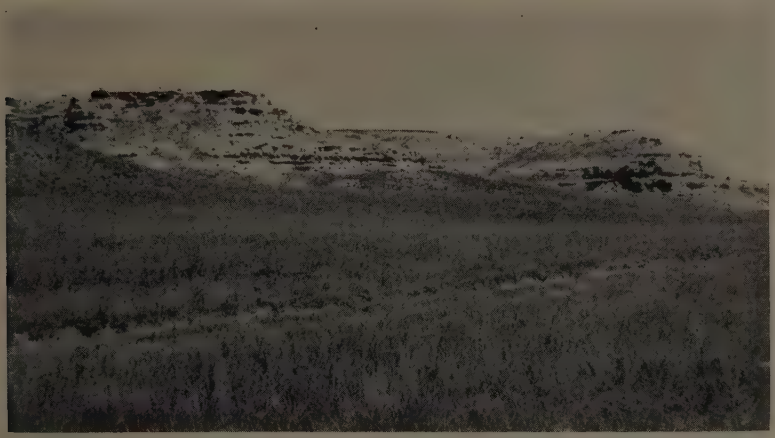

FIGURE 6. Horizontal layers of the Tertiary fronting on the Niobrara Valley. This section of the valley near Agate, Nebraska, is used for "wintering" range cattle. The trail in the foreground connects two ranchsteads located on adjoining holdings.

FIGURE 7. Line of dunes rising 200–250 feet along the northwestern edge of this basin offers protection to the ranch buildings (center background) from winter storms. Basin tracts usually furnish excellent grasses for grazing and haying.

Box Butte Tableland vary from 50 to 150 feet in height, and the tracts consist largely of assemblages of irregular grass-covered sand dunes with intervening basins and valleys (fig. 7). In a few instances they rise from 200 to 250 feet above the surrounding plain.

DRAINAGE

Scarcity of streams characterizes the tableland, with steep gradient tributaries of two major rivers, the North Platte and the Niobrara, draining the area. In general, tributaries of the North Platte drain the southern portion and those of the Niobrara, the northern. Both rivers carry water throughout the year, but in periods of exceptionally low precipitation and heavy withdrawals for irrigation purposes there may be little if any water visible in their beds. Losses through evaporation and sub-surface drainage are especially high in each stream.

Tributaries of the North Platte and Niobrara which have their *heads* in the Box Butte Tableland are not, for the most part, perennial streams. Although often carrying flood waters in the late spring or immediately following a summer thunderstorm of great intensity, they dwindle to mere trickles of water or disappear entirely during the months of July and August; this condition may continue throughout the fall season if precipitation is light. In the Wyoming section the North Platte River receives only one northside tributary of any consequence, Rawhide Creek, which drains approximately half of the Wyoming portion of the

FIGURE 8. Valley of Rawhide Creek offers an attractive site for ranchstead located a few miles southeast of Jay Em, Wyoming. Castle Rock in background adds much to the beauty of the place. The tower at rear of house, a so-called "wind charger", furnishes electricity for lights and small household appliances.

Box Butte Tableland. This stream heads a short distance to the west of Rawhide Buttes, draining a small part of the eastern front of the Hartville Uplift. It has some local importance in supplying water for livestock and irrigation. The valley of Rawhide Creek, while not large, is especially attractive where clumps and groves of cottonwoods, willows, and elm border the stream (fig. 8). In the Nebraska portion of the tableland occur numerous tributaries of the North Platte River, none of which has a drainage area as great as that of Rawhide Creek.

Only a few tributaries enter the Niobrara from the south, the more important being Whistle and Box Butte creeks. Box Butte Creek begins its course immediately east of Hemingford, Nebraska, and flows in an easterly-northeasterly direction, skirting Box Butte on the northwest. The remaining tributaries are of the sand-draw type, intermittent during most months of the year. Some of the tributary streams occupy valleys quite similar to the Niobrara in shape, but somewhat modified; others flow in deep canyons and are bordered by strips of bottom land only in their lower courses where gradients are much reduced.

A few small drainage ways, independent of either the North Platte or Niobrara rivers, do occur, particularly in the flatter sections of the area. One outstanding

tract of such drainage occupies the southeastern part of Box Butte County in the vicinity of Alliance, Nebraska. Here the drainage ways are intermittent with a northwest-southeast trend, losing whatever water they may carry through evaporation and seepage as they encounter the loose sands of the adjoining Sandhill Region on the east and southeast.

Largest of the intermittent streams is Snake Creek which heads in the sand dune area of southeastern Sioux County. This stream flows in a rather shallow valley, receiving most of its water, the volume of which is generally quite small, from numerous springs. Following an easterly course across Sioux and Box Butte counties, its waters are finally emptied into a drainage basin at the southeastern corner of Box Butte County. This depression extends eastward for some distance, with the sandhills bordering it on the north and south. In times of heavy precipi-

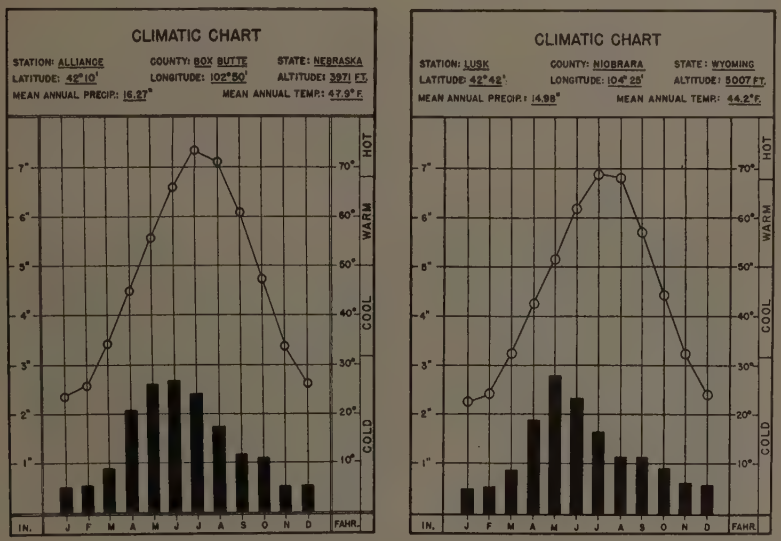

FIGURE 9. Climate determines largely the usability of an area or region, particularly for agricultural purposes.

tation Snake Creek empties so large a volume of water into the basin that there is much flooding of pasture lands, hay meadows, and ranchsteads; it may take several weeks for the excess water to seep away eastward through the loose sands.

In general the Box Butte Tableland is well-drained, with water standing only occasionally and then usually for but short periods in even the larger upland basins where the drainage has not been thoroughly established. Due to low precipitation, high rate of evaporation, the rather sandy nature of the soils, and the porous geologic materials underneath, drainage is quite satisfactory although in certain instances it may be excessive. Usually spring-fed, some marsh and swamp tracts occur; others are found along the watercourses and generally support a heavy grass cover.

CLIMATE

In its essential aspects the climate of the Box Butte Tableland is typically continental with middle latitude, semiarid characteristics (fig. 9): wide seasonal ranges in temperature with high maximums occurring during the months of July and August and correspondingly low readings in the winter season; rapid and

non-periodic changes in temperature, especially during the winter months when cyclonic storms reach their peak; wide diurnal ranges in temperature; mean annual precipitation of less than 17 inches, with a late spring and early summer maximum; dryness of the air; abundance of sunshine; and strong prevailing winds which are northerly and northwesterly in winter and southerly and southeasterly in summer. The area experiences a wide variety of weather phenomena: thunder and hail storms, tornadoes, and desiccating hot winds in summer; driving sleet storms, cold waves, and blizzards during the winter and spring seasons. Chinook winds can be expected during the spring, the warmth and dryness of which account for the rapid disappearance of snow, a heavy covering often melting within a few hours.

Changes in weather are frequent from day to day or from week to week, these short period weather conditions being due to the invasion of large air masses of different characteristics, such as warm, moist tropical air from the Gulf region;

FIGURE 10. Land abandonment, caused mainly by attempts to apply farming practices unsuited to a semiarid region, has been characteristic of the Box Butte Tableland since its early settlement. The sod house and clay-chinked shed as shown above are of common occurrence and many date back to the period immediately following passage of the Kinkaid Act of 1904.

hot, dry air from southwestern United States and northern Mexico; cool, moderately dry air from the north Pacific ocean; or cold, dry polar air from the vast Canadian interior (Blair, 1941).

Variability in the amount of precipitation received from year to year is one of the outstanding climatic distinctions of the Box Butte Tableland. Recurring periods of dry years have been of much importance in the area's history. Dry years bring suffering, and when they are too severe or continued too long, the people are brought face to face with disaster; the landscape becomes marked by weather-beaten abandoned homes (fig. 10), bleaching bones of livestock which have died of thirst and hunger, and uncultivated fields from which the winds whip clouds of dust. Although the area experiences drought, it is not an annual condition as there are humid intervals in short periods of years.

The thunderstorm is a common phenomenon and usually brings quick relief from the high temperatures of a summer day. Hail often accompanies the more violent storms and at times does much damage to livestock and crops. Blizzards are of common occurrence, the large masses of polar air sweeping down over the High Plains with disconcerting unexpectedness. Temperatures may drop 40–50° F.

in the space of a few hours, with resulting losses to livestock wintering on the more exposed portions of the ranges. Such storms generally occur during the late winter or early spring months but may be expected at any time from late October to the middle of May. Modern means of weather forecasting, based on air-mass analyses and the uses of rapid means of communication, especially the radio, have done much to reduce livestock losses by giving ample warning of approaching cold waves or snowstorms. However, if winter storms are of great intensity and long duration, such as experienced during 1948–1949, heavy losses in livestock as well as in human lives may be expected.

Inasmuch as the extent of the area studied is quite large, especially in an east-west direction, and since there is a pronounced slope from west to east, variations in climatic conditions are present. Table 1 gives a climatic summary for the stations located within the boundaries of the study area; the climatic summary for Lusk, Wyoming, based on a 40-year record, is also included because of its close proximity to the northwestern corner of the area which is without weather observation facilities.

FIGURE 11. Sagebrush tract bordering sand dunes in southern Box Butte County. The soil is exceptionally deficient in moisture as well as in plant nutrients. A "blow-out" appears at the top of the ridge to the left.

Precipitation

Agriculture on the Box Butte Tableland is dependent largely upon the yearly amount and distribution of precipitation; thus rainfall may rightfully be considered the most significant climatic factor in both crop and livestock production. The major difference between the Box Butte Tableland and the moister areas to the east and the drier areas to the west, lies in the fact that the rainfall of this upland tends to vary around a critical point for farming and ranching activities. Therefore even a slight reduction in precipitation seriously affects crop yields and stability of the livestock industry. Droughts west of the 100th meridian are often so severe and extended that they seriously limit a satisfactory rural economy. Man needs to recognize that periods of low precipitation are part of a climatic trend which runs its course beyond the range of human control, but that their influence can be greatly mitigated through careful application of agricultural methods adapted to semiarid conditions.

The amount of precipitation received on the Box Butte Tableland is determined chiefly by the strength and frequency of cyclonic storms, for this area is in the

TABLE 1

Climatic Summary

Station	County	State	Temperature					Killing Frost Average Dates				Average Precipitation													
			Length of Record	January Average	July Average	Maximum	Minimum	Length of Record	Last in Spring	First in Fall	Growing Season	Length of Record	January	February	March	April	May	June	July	August	September	October	November	December	Annual
			Yrs.	°F.	°F.	°F.	°F.	Yrs.			Days	Yrs.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Agate (Elev. 4,400′)	Sioux	Nebr.										8	0.34	0.78	0.71	1.79	2.46	3.11	2.22	1.40	1.43	0.71	0.21	0.48	15.59
Alliance (Elev. 3,971′)	Box Butte	Nebr.	47	23.4	73.1	106	—40	32	May 12	Sept. 27	138	52	0.52	0.55	0.89	2.05	2.60	2.64	2.38	1.72	1.18	1.09	0.53	0 54	16 27
Hemingford (Elev. 4,256′)	Box Butte	Nebr.										10	0.29	0.57	0.75	1.99	2.34	1.92	2.20	1.89	1.63	0.88	0.22	0.47	14.95
Sheep Creek C. (Elev. 4,200′)	Sioux	Nebr.										24	0.32	0.39	0.65	1.94	2.29	2.32	1.49	1.26	1.54	1.07	0.43	0 47	14 02
Lusk (Elev. 5,007′)	Niobrara	Wyo.	40	22.7	68.3	105	- 35	40	May 26	Sept. 18	115	39	0.43	0.50	0.82	1.66	2.95	2.40	1.61	1.18	1.07	0.85	0.43	0 60	14.50

Adapted from Climate & Man, Yearbook of Agriculture, 1941.

rain shadow of the Rocky Mountains. Normally the annual rainfall is less than 17 inches, and while the area may benefit from a late spring and early summer maximum, it is subject to great variability from year to year. Enough moisture does fall to induce a short grass vegetation, but on the whole trees fail to grow because of insufficient rain. Since much of the summer precipitation occurs during thunderstorms, rainfall is usually highly localized, erratic, and unreliable. Destructive hailstorms are not uncommon during this period, with the greatest number taking place in June and July.

TABLE 2

Normal, monthly, seasonal, and annual precipitation at Alliance, Box Butte County, Nebraska, 1890–1941. (Altitude—3,971 feet.)

MONTH	PRECIPITATION			
	Mean	Total amount for the driest year: 1934	Total amount for the wettest year: 1915	Snowfall average depth
	Inches	Inches	Inches	Inches
December	0.54	0.16	0.50	3.9
January	0.52	0.30	1.30	5.7
February	0.55	0.96	1.20	4.7
Winter Season	1.61	1.42	3.00	14.3
March	0.89	0.39	2.00	6.3
April	2.05	0.53	3.40	6.6
May	2.60	1.26	3.10	0.8
Spring Season	5.54	2.18	8.50	13.7
June	2.64	2.13	5.00	0
July	2.38	0.56	7.28	0
August	1.72	1.53	1.40	0
Summer Season	6.74	4.22	13.68	0
September	1.18	0.68	3.90	0.4
October	1.09	0.38	2.20	3.2
November	0.53	0.13	0.45	2.8
Autumn Season	2.80	1.09	6.55	6.4
Year	16.27	9.01	31.73	34.4

Tables 2–5 inclusive, prepared from data gathered by the United States Weather Bureau, present statistically some of the facts concerning the amount and distribution of rainfall at various points from east to west on the Box Butte Tableland and at Lusk, Wyoming, located in the western part of the Niobrara Valley and adjacent to the area. These stations vary considerably in altitude, Alliance having the lowest while Lusk has the highest.

The mean annual precipitation as recorded at Alliance, is 16.27 inches. This approximates 1⅓ acre feet of water per year, an amount hardly sufficient for satisfactory crop yields unless properly distributed throughout the growing season. The greatest annual precipitation ever recorded was 31.73 inches in 1915; there have been two other years with high precipitation records, 1892 with 24.75 inches and 1930 with 23.52 inches, but these fall far below the all-time 1915 record. The lowest precipitation recorded was 9.01 in 1934, a year of extreme drought throughout most of the Great Plains Region. The nearest approach to this record occurred in 1940 when 9.39 inches of rainfall were received. The annual amount

TABLE 3

Normal, monthly, seasonal, and annual precipitation at Hemingford, Box Butte County, Nebraska, 1909–1919. (Altitude—4,256 feet.)

MONTH	PRECIPITATION		
	Mean	Total amount for the driest year: 1910	Total amount for the wettest year: 1915
	Inches	Inches	Inches
December	0.47	0.32	0.40
January	0.29	0.37	0.51
February	0.57	0.19	1.95
Winter Season	1.33	0.88	2.86
March	0.75	0.40	1.64
April	1.99	0.63	3.70
May	2.34	2.04	3.25
Spring Season	5.08	3.07	8.59
June	1.92	2.28	3.51
July	2.20	1.73	4.06
August	1.89	0.62	4.29
Summer Season	6.01	4.63	11.92
September	1.63	0.97	3.53
October	0.88	0.41	1.09
November	0.22	0.18	0.04
Autumn Season	2.73	1.56	4.66
Year	14.95	10.14	28.03

TABLE 4

Normal, monthly, seasonal, and annual precipitation at Sheep Creek Camp No. 5, Sioux County, Nebraska, 1918–1941. (Altitude—4,200 feet.)

MONTH	PRECIPITATION			
	Mean	Total amount for the driest year: 1939	Total amount for the wettest year: 1930	Snowfall average depth
	Inches	Inches	Inches	Inches
December	0.47	0.35	0.11	4.9
January	0.32	0.65	0.54	3.3
February	0.39	1.08	0.50	3.6
Winter Season	1.18	2.08	1.15	11.8
March	0.65	0.50	0.18	4.8
April	1.94	0.48	3.51	5.1
May	2.29	0.43	4.65	0.4
Spring Season	4.88	1.41	8.35	10.3
June	2.32	1.71	0.37	0
July	1.49	1.00	0.56	0
August	1.26	0.76	4.00	0
Summer Season	5.07	3.47	4.93	0
September	1.54	0.80	2.83	0.2
October	1.07	0.32	3.92	1.8
November	0.43	0.00	0.15	4.5
Autumn Season	3.04	1.12	6.90	6.5
Year	14.02	8.08	21.32	28.6

of snowfall varies from a trace to several feet, the mean annual being about 34.4 inches. The mean annual precipitation recorded at Lusk is 14.98 inches.

The light precipitation is reflected strongly in the vegetation, such as the short grasses, the failure of native trees to occupy the land except in scattered clumps along the more important drainage ways, and the presence of sagebrush in small tracts of Box Butte and Sioux counties, Nebraska, with larger areas in Goshen and Niobrara counties, Wyoming (fig. 11). The fact that climate favors the growth of grass rather than trees, has helped to make this tableland an important grazing section of the West.

TABLE 5

Normal, monthly, seasonal, and annual precipitation at Lusk, Niobrara County, Wyoming, 1889–1941. (Altitude—5,007 feet.)

MONTH	PRECIPITATION			
	Mean	Total amount for the driest year: 1914	Total amount for the wettest year: 1942	Snowfall average depth
	Inches	Inches	Inches	Inches
December	0.56	0.18	0.27	6.4
January	0.47	0.12	0.28	4.9
February	0.53	0.02	0.48	5.6
Winter Season	1.56	0.32	1.03	16.9
March	0.89	0.06	0.82	6.4
April	1.88	4.39	5.00	9.2
May	2.79	2.33	4.59	2.2
Spring Season	5.56	6.78	10.41	17.8
June	2.37	0.85	3.13	0
July	1.66	0.14	3.29	0
August	1.15	0.30	1.02	0
Summer Season	5.18	1.29	7.44	0
September	1.15	0.00	2.06	0.5
October	0.93	0.45	1.83	2.2
November	0.60	0.00	1.10	2.9
Autumn Season	2.68	0.45	4.99	5.6
Year	14.98	8.84	23.87	40.3

Variations in rainfall from year to year, and from a period of wet years to one of dry years, are well depicted by the productivity of the area as well as by the activities of the people. Rainfall is usually inadequate for the raising of crops common to the humid areas to the east unless irrigation or dry-land farming methods are employed. In some years to be sure, there is enough moisture to make dry farming and irrigation unnecessary, but in other years crops would certainly fail without them. Of the annual amount received, 77 percent falls from April to October inclusive, and more than 58 percent during the critical crop months, May to October, at which time the optimum conditions for evaporation prevail and transpiration reaches its maximum. In June, 16 percent of the total annual precipitation occurs, and in January, 3 percent.

The Alliance records show that the spring months, March to May inclusive, receive an average precipitation of about 5.54 inches or 34 percent of the mean annual. March receives a monthly average precipitation of 0.89 inches; April,

2.05 inches; and May, 2.60 inches. It is readily seen from these figures that there is a marked increase in the amount of precipitation received from the beginning to the end of the spring season, during which period the precipitation occurs in the form of rain or snow, or both. Occasionally there are prolonged periods of raw, drizzly weather and at such times practically no runoff takes place due to the gently falling of the rain, the porous nature of the soil, and the grass sod covering the greater portion of the tableland. Such rains are deemed especially favorable agriculturally because spring moisture is essential for small grains as well as for legumes and pasture lands; they also aid materially in the preparation of the seed bed for corn and grain sorghums.

The summer season, June to August inclusive, receives the greatest seasonal rainfall which totals 6.74 inches or about 40.8 percent of the mean annual. June, the wettest month of the entire year, has an average rainfall of 2.64 inches. Average precipitation for July is 2.38 inches, and for August 1.72 inches. During these months the rains are apt to be brief and pounding, temperatures high, humidity low, long periods of sunshine uninterrupted except for quick violent storms, and wind persistent and strong—all of these weather conditions tend toward greatly increasing evaporation, thereby considerably reducing rainfall effectiveness. Any variation from the normal annual or seasonal precipitation received interferes seriously with production of tillable crops, even though in some cases such variations may be above normal. The spring rains in 1942, for example, were unusually late and persisted so long that it was practically impossible to plant crops in sufficient time to assure their maturity before the first killing frost.

The fall or autumn season, September to November inclusive, has an average precipitation of about 2.80 inches, approximately 17 percent of the annual amount. Precipitation occurs mainly in the form of rain, most of which falls during occasional and irregular periods of cold, drizzly weather. The autumn moisture is essential to plantings of winter wheat and fall rye, both usually sown the latter part of September. Fall rains are favorable to the growth of lowland pastures upon which many ranchers depend in part for the feeding of livestock during the winter months.

The winter season, December to February inclusive, is a relatively dry season and has an average precipitation of only 1.61 inches, which is but 9.7 percent of the annual amount. January is the driest month, receiving only 0.52 of an inch of precipitation, as well as the coldest month of the entire year with an average temperature of 23.4° F. Precipitation during the winter season occurs mainly in the form of light snow which has its origin in cyclonic storms. These storms generally move with great rapidity, giving to the winter season highly changeable weather. When the snow forms a blanket over fall grains, it not only protects these crops from low temperatures and strong winds, but also contributes to the supply of soil moisture, thereby often improving the agricultural outlook for the coming year.

Temperature

Cyclonic and anticyclonic storms, resultant of air mass movements from the colder northern regions and from the warmer southern ones, create frequent changes of temperature as well as of wind direction and velocity. Temperatures of the semiarid continental climate, such as experienced on the Box Butte Tableland, resemble those of the humid continental type, except that the extremes are greater. Table 6 presents statistically some of the data concerning the temperatures recorded at Alliance between 1895–1941.

The average annual temperature for Alliance, based upon a 46-year record, is 47.9° F., and the annual range in monthly means varies from 23.4° F. in January to 73.1° F. in July. Temperatures often reach 100° F., or more during July and August. The highest ever recorded was 108° F. on July 20, 1939, while the lowest was −40° F. on February 11, 1899; these two extremes give an absolute range of

148° F. The average annual temperature recorded at Lusk over a period of 50 years, is 44.2° F. which is 3.7° lower than that given for Alliance.

The spring months are generally cool and delightful with the number of crisp, sunshiny days far exceeding the cloudy ones. March is a month of great extremes, a period of transition from winter to spring with an average monthly temperature, as recorded at Alliance, of 34.5° F. in contrast to 45.3° F. for April and 55.9° F. for May. A comparison of average monthly temperatures for the spring months shows that there is a general increase of nearly 0.25° F. per day as the summer season approaches with an accompanying weakening of cyclonic and anticyclonic storms.

TABLE 6

Normal monthly, seasonal, and annual temperature at Alliance, Nebraska.
(Altitude—3,971 feet.)

MONTH	TEMPERATURE		
	Mean	Absolute Maximum	Absolute Minimum
	° F.	° F.	° F.
December	26.0	34.4	16.0
January	23.4	32.3	8.6
February	25.7	35.4	8.5
Winter Season	25.0		
March	34.5	43.2	21.5
April	45.3	51.9	37.4
May	55.9	66.4	48.2
Spring Season	45.2		
June	66.0	74.0	57.4
July	73.1	80.6	68.2
August	70.9	76.4	63.4
Summer Season	70.0		
September	60.6	67.4	51.2
October	47.4	54.8	32.0
November	33.9	43.3	22.9
Autumn Season	47.3		
Year	47.9		

Summer days are usually quite warm and since the atmosphere is dry and clouds and fog rare, much sunshine prevails. Nights may be cool, the result of moderate altitude and rapid radiation, the latter being consequent upon dry air and clear skies. The summer months have an average temperature of 70.0° F.; June averages 66.0° F.; July, the hottest month of the year, 73.1° F.; and August, 70.9° F. Periods of hot days may be expected during the summer season, especially in July and August, and when they occur over a long period of time with little precipitation, damaging droughts are likely to ensue, especially when accompanied by desiccating southerly winds.

With the passing of summer into the autumn season, temperatures show a steady decrease, dropping from a monthly average of 60.6° F. for September to 47.4° F. for October, and 33.9° F. for November. The change from autumn to winter is more gradual than from winter to spring; clear, mild, frosty days and nights may prevail without notable change until December. The moderate

temperatures of early autumn are often broken by short periods of chilly, stormy weather.

The winter season brings considerable temperature variability. Cold waves, during which the thermometer may drop 20° F. or more in a period of 24 hours, can be expected. The average for December is 26.0° F.; January and February are not only the coldest months of the year but hold the record for minimum temperatures. According to the Alliance records, February has had a low of −40° F. The monthly average for January is 23.4° F., and for February 25.7° F., with the temperatures rising rapidly after the latter month. Northerly and northwesterly winds are common during the winter season.

The growing or frost-free season decreases from about 138 days at Alliance, to approximately 115 days in the northwestern part. Latitude and altitude determine largely the differences in the length of the growing season from southeast to northwest. The average spring date for the last killing frost at Alliance is May 12 and at Lusk, May 26; the average autumn date for the first killing frost for the same stations is September 27 and September 18.

Sunshine and Cloudiness

Winter months give rise to brief periods of cloudy weather. The somewhat cloudy spring season with its periods of drizzly weather is most suitable for small grains; the much needed sunshine for grain development and maturity comes during the summer months. Autumn days are generally sunny, an excellent condition for the proper drying of the corn crop as well as for preparing the ground for potato harvesting. Such days also favor the continuance of livestock grazing.

Winds

Winds on the Box Butte Tableland are highly changeable throughout the year, due to the prevalence of cyclonic and anticyclonic storms moving eastward across the area. There is much wind, but no records of wind velocity have been kept at either the Alliance or Lusk weather stations. Records of prevailing wind direction have been kept at both places however and these show that during the period from about November to March inclusive, the prevailing wind direction is northerly and northwesterly. During the remainder of the year it is mainly from a southerly direction. The summer winds are warm and in late July and August have a pronounced drying effect. The high rate of air movement increases evaporation, intensifies droughts caused by rainfall deficiencies and high temperatures, and propagates heavy dust storms which are often referred to as *black blizzards*.

Winds although certainly variable, are quite dependable, a fact attested to by the popularity of the windmill for pumping water to meet livestock and domestic requirements; also wide-spread use of the *wind charger* for furnishing lights, and in some instances, power. While windstorms do occur and at times result in local damage, they are not especially destructive except when accompanied by hail.

There are those who believe the climate of the Box Butte Tableland is gradually changing but the same has been said regarding other areas as well. Such a conclusion is no doubt due to faulty reasoning, poor memory, and much wishful thinking. It is perhaps entirely true that the climate of this upland as well as that of any other area is subject to more or less prolonged fluctuations, but climatic records kept over a period of more than fifty years fail to show any definite evidence of material progressive changes.

NATIVE VEGETATION

The tableland, lying in a zone of transition from humid to arid conditions, is characterized by a short, native grass cover (fig. 12). In many sections the area has the appearance of a vast meadow land, sometimes green, sometimes brown, depending upon the season and amount of rainfall received. Since the greater

portion of the annual precipitation occurs during the spring and early summer months, the grasses achieve their greatest growth in this period. Many of the grasses cure upon the ground during the late summer and early fall, offering excellent grazing for livestock in the winter months if snowfall is light. Vigor of the grasses varies greatly with the rainfall from year to year and thus there is a close correlation between the grasses and the number and quality of livestock raised. Owing to the depth and compactness of the sod, and the general lack of trees, the pioneer made extensive use of the prairie sod in the construction of houses and barns.

The grasses, generally speaking, can be divided into two principal groups, namely, the short grasses, and the tall grasses (Greenslet, 1929). The short grasses are shallow-rooted and occupy areas in which the moisture penetration usually does not exceed two feet. The tall grasses on the other hand are, comparatively speaking, deep-rooted and grow where moisture penetration is greatest.

FIGURE 12. An excellent stand of grasses bordering a strip of sand hills. Such ranges are a valuable adjunct to every cattle ranch. Part of the grasses will be cut, stacked, and held in reserve for winter feeding.

These latter grasses, although generally limited to valley areas, do occur in upland swales where runoff from adjacent lands causes favorable moisture conditions in the low-lying basins. The valley and basin tracts usually produce a good growth of grasses and therefore are important for native hay production.

Sages, as previously indicated, are found in southwestern Box Butte, southern Sioux, on large tracts in Goshen, and to a limited extent in Niobrara County southeast of Van Tassel, Wyoming. Some of the plants grow to heights of four feet or more; a few are suitable for browsing by cattle and sheep although the nutritious value of the sage is considered low at best.

The abundance of wild flowers in late spring or early summer is noteworthy. The water lily is found in the marshlands; the dandelion, in the low-lying meadows; and the wild rose, prairie daisy, and sun flower, on the uplands. The dandelion maintains itself rather precariously in competition with the more hardy of the native grasses.

Prior to the advent of cattle barons, sheep herders and settlers, there existed a more or less continuous sod where an equilibrium had been established between the various forms of plant life living together in the same region. The native grasses such as western wheat grass, buffalo grass, needle grass, the bluestems and the gramas had developed resistance to the climatic hazards encountered. The same was also true of the wild animal life. This so-called *balance of nature* was

upset by the incoming of stockmen and farmers so that today many of the less desirable grasses have increased at the expense of the better ones, a condition due largely to over-grazing. Introduction, through farming, of many undesirable foreign species has also helped to bring about this change. Prickly pear, a type of flat-jointed cactus, has moved into areas where the original grasses have been injured or destroyed; the spread of this plant is exceedingly rapid during periods of drought, especially on lighter soils.

Although the tableland is nearly treeless, it is not so devoid of tree life as commonly believed by people not familiar with the area. Clumps of cottonwood, willow, and elm are encountered along portions of the major streams; western yellow pine and red cedar, and quaking aspen occur on the Rawhide Buttes, along the upper slopes of Pine Ridge (Goshen County, Wyoming), and in some canyon tracts of the Hartville Uplift. Trees along the crest of Pine Ridge, while rarely attaining a diameter of more than two feet and a height of over sixty feet, are a prominent feature of the landscape in that part of the tableland.

SOILS

There is perhaps no environmental element of more significance in determining the industry of a rural population or its success than is soil. The true character of agricultural possibilities is revealed by the soil and he is indeed a wise man who selects that soil best suited for his specific needs. The geographic importance of soil is not so easily perceived or recognized as are the characteristics of climate and differences in relief, but it is nevertheless equally significant. Soils of the Box Butte Tableland represent both residual and transported types, the latter soils displaying eolian as well as alluvial characteristics. Derived largely from disintegration of the underlying Arikaree formation, the soils are chiefly a mingling of silt and fine sand, generally quite rich in lime.

From east to west across the tableland there is a definite change in soil coloration, ranging from a dark to a light brown. This is due chiefly to a decrease in humus content, indirectly occasioned by a lessening of precipitation. The semiarid conditions necessitate careful handling in order to prevent collapse of the soil structure, a situation easily brought about because of low rainfall, insufficiency of humic materials, and rapid destruction by wind and water when not protected by a vegetative covering (fig. 13). Improper handling of the soil generally causes severe slumping and the resulting powdery mass is easily and quickly removed by the wind; the soil then piles up along fence rows, in road ditches, and around buildings, or is carried to distant areas.

The soils are largely pedocalic. In a few instances they are alkaline and give rise to alkali-incrusted flats which are of practically no value for either tillage or grazing. Box Butte Tableland soils are generally of higher fertility than those of humid regions because the soluble constituents necessary to the growth of plants are less leached. The common soil deficiency is not in plant food but in moisture, a condition susceptible of some solution through the adoption of dry farming practices and limited irrigation. Some of the soils are very sandy and used chiefly for grazing purposes.

In view of the fact that soil is the greatest single natural resource of the Box Butte Tableland, the future of the area will continue, as it has in the past, to be closely bound to the land and the use which man makes of it. Misuse of the soil quickly invites disaster and this area, like other parts of the High Plains Region, has had its share of misfortune because of improper land use.

NATIVE WILD LIFE

The Box Butte Tableland supports a fairly abundant wild life. Here are found antelope, deer, coyote, fox, wolf, bobcat, and badger. Some of the smaller

denizens are the skunk, jack rabbit, prairie dog, beaver, muskrat, and mink. None of the animals or rodents mentioned, excepting the jack rabbit and prairie dog, appear in any large number although during Indian occupation they were numerous as was also true of the American bison and elk. Several of the animals such as deer, antelope, and beaver, are now protected by state and federal laws. The coyote and wolf prey upon both wild game and livestock; at times these animals cause serious losses to farmers and ranchers.

A few varieties of snakes occur and of these the rattlesnake is the most venomous. During the summer and early autumn months a rattler may be expected almost anywhere. In late fall the snakes seek their dens, usually to be found in outcrops of the underlying bedrock formations. On warm fall days it is not an uncommon sight to observe numerous rattlesnakes lying among the rocks and basking in the sunshine. With the advent of cold weather the snakes crawl into the dens and do not appear again until late spring.

FIGURE 13. Approximately six inches of the top soil, loosened by plowing and unprotected by a vegetative cover, has been swept away by high winds. The land, now abandoned, offers no encouragement to others.

Bird life is plentiful. The most common are the gull, eagle, hawk, owl, curlew, meadow lark, mocking bird, flicker, bob white, robin, magpie, and grouse. The prairie chicken has largely disappeared, but in its place has been introduced the pheasant. Ducks and geese, like the pheasant, are common game birds and much sought after by hunters. The bird life not only adds beauty and interest to the area but does much good in destroying insect life harmful to both the native vegetation and cultivated crops. Among the harmful insects the grasshopper and blister beetle are perhaps the best known and usually do the greatest amount of damage.

WATER RESOURCES

The water supply of any area is of great importance but it takes on a special significance in such semiarid regions as the Box Butte Tableland. The quality as well as the quantity of available water is of great concern to the inhabitants. Water supplies are derived from two main sources, namely, surface water and ground water, with the latter secured from the fluviatile mantle of the uplands and from the alluvial deposits in the valleys.

Surface water is exceedingly limited, with Box Butte, Snake, and Rawhide creeks supplying the bulk. Following heavy rains a number of ponds appear on the flat phase of the tableland, but these generally last only a few days at best and

are therefore of little value as watering places. Some artificial stock ponds have been constructed and while not extensive, they have proved their worth as reservoirs of runoff waters. Kilpatrick Lake, man-made, is the only sizable body of water on the entire tableland; this lake, with a surface area of about forty acres, and located on Snake Creek in western Box Butte County, is supplied by both surface runoff and springs. A few small lakes are usually found in the eastern part of the same county, especially along the fringes of the sandhills.

Scarcity of surface water has caused the tapping of ground water sources, and fortunately the supply seems to be abundant. Apparently it is rapidly replenished by subterranean flow from the west and northwest as well as through local precipitation. The absorption of rainfall is especially high in the sections where the underlying bedrock is near or at the surface. A dense clay formation forms an impervious seal and the ground water occurs within the overlying Tertiary materials. The ground water has a particular advantage in the fact that it is relatively cold, the temperature varying from 50° to 54° F.

On the tabular sections of the upland the ground water table lies at depths varying from 150 to 300 feet as indicated by differences in the depths of wells throughout the area. Usually the wells are located in low-lying places so as to more readily tap the underground supplies. There are some instances where wells have been drilled directly on the crest of a ridge or hill in order to obtain greater windmill efficiency. In a few cases two or more windmills have been placed side by side on some prominent point because the location proved exceptionally good for watering range stock.

Although the quality of the water is excellent, the chief drawback to underground supplies is the depth at which they often lie. Well drilling is expensive and the costs have greatly retarded the development of pump irrigation on upland areas. According to the Conservation and Survey Division of the University of Nebraska, there are approximately forty irrigation wells in the Nebraska portion of the Box Butte Tableland, varying in depth from 93–458 feet and irrigating about 5,242 acres. In the larger basin areas and drainage ways, satisfactory water supplies for livestock and domestic purposes are within twelve, eighteen, and thirty feet of the surface. Introduction of the windmill was a boon to the area and today it is certainly *land of the windmill*. This is due to favorable wind conditions, a pressing need of water for farm and ranch use, and the general lack of permanent streams.

Ground water resources are of immeasurable value to the tableland. Droughty conditions cause the loss of most surface water, leaving the underground supplies in many instances the only source. With a better stabilization of agriculture in this part of the High Plains Region it is to be expected that more and better wells will be put down; farmers and ranchers will continue to develop limited pump irrigation in order to assure themselves of adequate water supplies for crops and livestock. At the present time one can hardly predict what influence these increased demands will have upon the present level of the water table; such demands may cause a lowering of the water table, resulting in the loss of many wells now considered satisfactory.

TRANSPORTATION

The people living on the Box Butte Tableland, like those in most sections of the semiarid and arid West, have always been confronted with the problem of adequate transportation facilities, due largely to the sparseness of population as well as to the general low productivity of the land. During the early period of settlement the only means of transportation other than by stagecoach and freighter, was that offered by the railroads; in more recent years highways have played an ever increasing role in breaking down the isolation of farm and ranch, village and town.

Main line of the Burlington Railroad from Kansas City, Missouri, and Lincoln, Nebraska, to Billings, Montana, passes through Alliance, Hemingford, and Crawford, Nebraska. Alliance is a division point of the Burlington as well as a junction for the Burlington's line to Denver, Colorado. The central and western sections of the tableland are without railroad facilities and therefore must depend chiefly upon the Chicago and Northwestern Railroad's line extending from Omaha, Nebraska, and Sioux City, Iowa, to Lander, Wyoming, and upon the North Platte Valley lines of the Burlington and Union Pacific. The Chicago and Northwestern more or less follows the Niobrara from Glen, Nebraska, to Lusk, while the Union Pacific traverses the valley of the North Platte into Wyoming.

FIGURE 14. A poorly graded road makes travel difficult. This "country road" is the only route of travel available to several widely separated ranchsteads. Heavy rains and snows may close such roads for weeks at a time, thus adding to the ever present problem of isolation.

The area is better served by highways than by railroads, but still there are large sections remote from highway facilities. Two federal routes tend to parallel the tableland. Federal Highway No. 26 follows the North Platte Valley from Lewellen, Nebraska, to Guernsey, Wyoming, passing en route through the valley towns of Oshkosh, Lisco, Broadwater, Northport, Minatare, Scottsbluff, Mitchell, Morrill, and Henry, Nebraska, and Torrington, Lingle, and Fort Laramie, Wyoming. To the north of the upland is Federal Highway No. 20. This route passes through the White River Basin of northwestern Nebraska, across the Dawes Tableland to the vicinity of Van Tassell, Wyoming, and then follows along the valley of the Niobrara River to Lusk and beyond. The only federal highway crossing the area is Highway No. 85, and it traverses the western section, connecting Lusk and Lingle.

Four state highways serve portions of the Nebraska section of the Box Butte Tableland and connect with federal highways. State Highway No. 2 enters Alliance from the east, turns northwestward and passes through Hemingford, Marsland, and Crawford. This road offers a direct route from Alliance to the Black Hills area of South Dakota. State Highway No. 19, a part of the Denver-Black Hills Highway, extends from Alliance southward to the North Platte Valley

and northward to Chadron. State Highway No. 87 enters Hemingford from the east and follows a westerly and southwesterly route to Scottsbluff. State Highway No. 29, a secondary graveled road, connects Mitchell and Harrison. Bus service is to be had only on state highways No. 2 and 19, or on federal highways No. 20 and 26. Western Air Lines normally operates two flights daily between Denver and Minneapolis, with stops at Alliance.

In considering the low population density, approximately five persons per square mile, it might be said that transportation facilities on the Box Butte Tableland are adequate. However, it should be recognized that from the viewpoint of the general welfare of a people this area is inadequately served by both railroads and highways, facilities which do much toward making possible the normal social development of a people. Still, it is not to be expected that any additional major routes of transportation will be developed in the near future because the general sparseness of the population and low productivity of the land do not warrant sizable expenditures. Much of the area will remain in dependence upon unimproved roads (fig. 14) and primitive trails for connections with the existing highways, and distance will continue to hinder social contacts and retard the movement of commodities between farm and ranch to the ultimate consumer as well as between factory and the rural buyer.

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Geography of the USSR, A Regional Survey. *Theodore Shabad.* Columbia University Press, New York. 1951. xxxii+584 pp. $8.50.

The author has divided the volume into two parts. Part I, covering only 92 pages, is a general survey of the physical features, the political framework, and the economic pattern of Russia. The 405 pages of Part II are devoted to a factual account of the current geography, population, agriculture, industry, and transportation for each of the major political divisions and subdivisions of the country.

For those interested in a general but limited survey of the USSR without becoming involved in a detailed account of the various political divisions, the first part appears to fulfill the need. The encyclopedic nature of the second part, based on a regional division by political units rather than a treatment of the country from the geographic standpoint, detracts from the suitability of the book as a geography text. Its value for reference purposes, however, especially to non-Russian reading students, is superior to most studies dealing with the Soviet Union.

The author's objective in presenting "an up-to-date treatment of the geography" of Russia seems to have been basically fulfilled. The wealth of current information, as well as maps, in the body of the text should be of great value to those desiring a more intimate knowledge of the present-day geography of the country. The statistical tables, based upon Soviet sources, and the bibliography in the appendix add considerably to the usefulness of the book. However, the lack of illustrative material depicting the geographic nature of the country will be missed by those accustomed to standard geographic publications.

GEORGE M. TAOKA.

PRINCIPAL TYPES OF VEGETATIVE SHOOT APEX ORGANIZATION IN VASCULAR PLANTS[1]

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Before progress can be made in research, a problem must be recognized. Once the problem has been perceived, a research program may be directed toward a solution. The problem of how and where a shoot grows and the organization of the shoot apex was apparently first conceived by Kaspar Friedrich Wolff (1759). Although his observations on the structure, formation, and growth of cells were fantastically inaccurate, he made a great contribution to our knowledge of the growing plant by setting forth a new and important problem. In a very real sense, Wolff is the father of developmental plant anatomy.

Disagreement is the life blood of many research problems. Strenuous opposition is often engendered by a dogmatic statement or a theory which is proposed as a universal truth. Opposition to Wolff's (1759) original proposition regarding the organization and growth of shoot apices prompted plant anatomists, some 85 years later, to investigate the truth of the statement. The factual solution of the problem of shoot apex organization had its beginnings in the work of Nägeli (1845). Following this work on many lower cryptogams, Nägeli concluded that the cells of all tissues of the shoot of cryptogams and higher plants have their genesis in a single apical cell. The new-born apical cell theory supported by Hofmeister (1851) and others provided the impetus for a renewed, vigorous attack on the problem of shoot apex organization. A little later a new proposal, Hanstein's (1868) histogen theory was born of more careful observations and in a mind unfettered by the prevailing fanaticism of the apical cell theorists. The histogen theory in turn, sparked another rigorous attack (Pringsheim, 1869; Strasburger, 1872; Warming, 1872; Kny, 1878; Klercker, 1885; Groom, 1885; Dingler, 1866; Douliot, 1890; Koch, 1891, 1893; Schmidt, 1924; Foster, 1935; Korody, 1937; and others) on the problem of shoot apex organization. It would seem that Hanstein's principal contribution to the subject of shoot apex organization was his recognition (1) of the dissimilarity in structure between the shoot apices of vascular cryptogams and phanerogams and (2) that the apices of angiosperms are constituted of growth zones. More recently Schmidt (1924) proposed the tunica-corpus theory as the result of additional and more accurate observations on the structure of the angiosperm shoot apex. Schmidt accepted Hanstein's basic thesis that angiosperm shoot apices exhibit growth zones, but disagreed with the unrealistic zonal pattern suggested. Schmidt's new zonal pattern concept distinguished the two zones (tunica and corpus) by their intrinsically different manner of growth. One of the factors which accounts for the present day interest and emphasis on studies concerning the organization and growth at shoot apices is the disagreement (Majumdar, 1945; Dermen, 1947; Reeve, 1948; Popham and Chan, 1950; and others) concerning the validity and general suitability of Schmidt's terminology.

In the author's opinion sufficient observations have been made on shoot apex organization and the relation of zonal patterns to shoot growth to make a systematic summary of them worth while. It is the writer's intent to summarize and classify the accumulated information so as to present a view of the basic organizational patterns encountered to date in the shoot apices of vascular plants. In addition, it is hoped that this paper will be a unifying basis for future investigations and

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discussions concerning the organization of shoot apices. Certain inconsistencies will become apparent to the reader and it is hoped that these will provide the stimulus for further research. Whether the number of types suggested will be increased or decreased as time goes by is of little importance. Whether each plant is correctly typed will depend upon the accuracy and thoroughness of the recorded observations on that plant. It would indeed prove amazing if all of the plants herein typed were later found to be classified correctly in the light of further investigations.

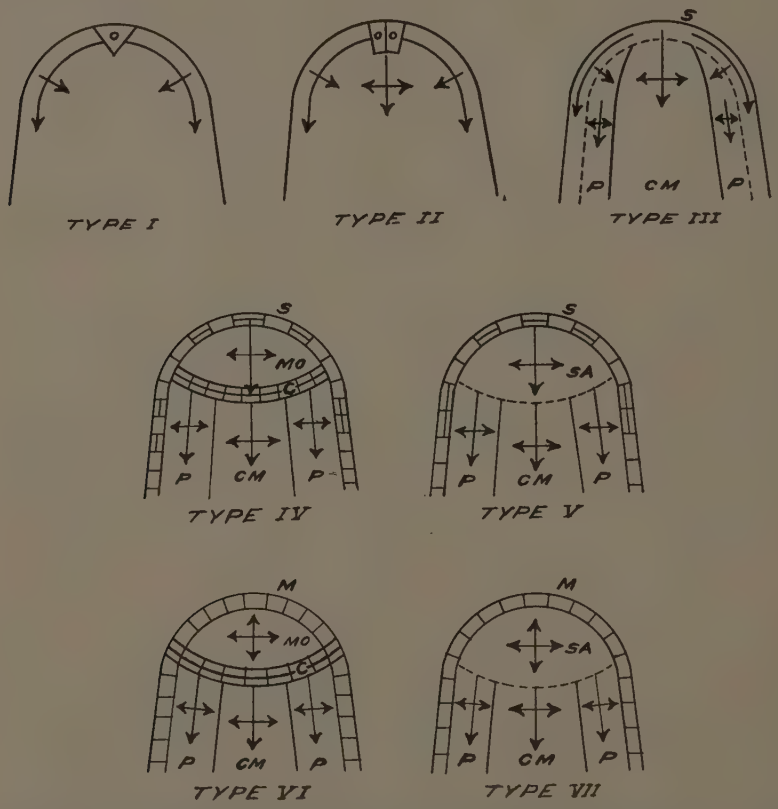

FIGURE 1. Diagrammatic representations of longisections through shoot apices illustrating the seven principal types of organization found among vascular plants. (S, surface meristem; M, mantle; MO, central mother cells; C, cambium-like zone; SA, sub-apical initials; CM, central meristem; P, peripheral meristem.)

It is not within the scope of this paper to discuss in detail the various theories of shoot apex organization. This has already been done by such able authors as Schüepp, 1926; Foster, 1939b, 1941a, 1949; Sifton, 1944; Wardlaw, 1945; Majumdar, 1945. Neither is it planned to discuss in detail the genetic, phylogenetic, and growth-form implications of each type of apical organization. These

aspects have already received the attention of numerous authors (Bower, 1889, 1890–91; Satina, Blakeslee, and Avery, 1940; Cross, 1941, 1942; Satina and Blakeslee, 1941, 1943; Dermen, 1945, 1947).

No attempt has been made to recite all of the facts reported by investigators (particularly the early investigators) whose works have been superseded by more thorough investigations and re-evaluated in the light of additional data. It has already been suggested that many of the early investigators labored during a period when only one concept of shoot apex organization (the apical cell theory) was prevalent. In addition to this limitation, the theory was supported by leading plant anatomists whose reputations as careful investigators were not to be doubted. In the light of (1) the vigorous support accorded the single theory of shoot apex organization, (2) poor microtechniques, and (3) poor optical equipment, it is remarkable that so many of the data obtained by the earlier workers have stood the acid test of reinvestigation.

Based on the facts now available, shoot apices of vascular plants may be grouped, with reference to differences in their cellular organization, into seven distinct categories (fig. 1).

TYPE I. FERN TYPE

In the first of these categories may be placed a group of pteridophytes having a *single apical cell* located at the summit of the shoot apex. The apical cell may be two-sided (three faced), both sides being convex, or it may be an inverted three- or four-sided (four or five faced) pyramidal cell. In any case the single apical cell occupies the summit position of the shoot apex and is the forerunner of all of the cells in the shoot apex. New cells are formed from the apical cell by a regular sequence of divisions in which the new cell walls lie parallel to the side walls of the apical cell. Each division of the apical cell results in two dissimilar cells, one of which enlarges and assumes the characteristic features and size of the original apical cell. Anticlinal and then periclinal cell divisions occur subsequently in the other cell newly formed from the initial. The cells thus formed later differentiate into the tissues of the shoot. No cell walls form parallel to the "base" of the initial, which lies at the surface of the shoot apex. For this reason the apical cell remains at the summit, with one surface exposed to the atmosphere.

Some of the plants which have shoot apices belonging to Type I are listed below.

Niphobolus chinensis	Apical Cell with two convex sides	(Hofmeister, 1862)
N. rupestris	"	" "
Selaginella hortensis	"	" "
S. galeotii	"	" "
S. martensii	"	(Pfeffer, 1871; de Bary, 1884)
S. umbrosa	"	(Wand, 1914)
Azolla sp.	"	(de Bary, 1884)
Salvinia natans	"	(de Bary, 1884; Zawidzki, 1912)
Pteris aquilina	"	(de Bary, 1884; Chang, 1927)
Polypodium rupestre	"	(de Bary, 1884)
P. lingua	"	" "
P. aureum	"	" "
P. punctatum	"	" "
P. phymatodes	"	" "
Platycerium alciorne	"	" "
Pteridium sp.	"	(Bower, 1923)
Nephrolepis undulata	Biconvex or three-sided pyramidal apical cell	(de Bary, 1884)
Polypodium vulgare	"	" "

Equisetum arvense	Three-sided (tetrahedral pyramidal apical cell	(Cramer, 1855)
E. limosum	"	(Reess, 1867)
E. hiemale	"	" "
E. variegatum	"	" "
E. palustre	"	(Vidal, 1912)
E. scirpoides	"	(Johnson, 1933)
Ophioglossum vulgatum	"	(Hofmeister, 1857)
Marsilea vestita	"	(Hanstein, 1865–66; Campbell, 1905)
Psilotum triquetrum	"	(Solms-Laubach, 1884; Ford, 1904)
Pilularia sp.	"	(Bower, 1889)
Amphicosmia walkerae	"	" "
Ceratopteris sp.	"	" "
Hymenophyllaceae	"	" "
Lygodium scandens	"	" "
Aneimia hirta	"	" "
Tmesipteris sp.	"	(Holloway, 1917, 1921)
Osmunda cinnamomea	"	(Cross, 1931)
Selaginella wildenovii	"	(Barclay, 1931)
S. sinensis	"	(Hsü, 1937)

Selaginella martensii (Treub, 1876) is an interesting example of a plant with a variable Type I organization. The sporeling stages show a four-sided pyramidal cell at the shoot apex while older plants have a three-sided pyramidal cell or an apical cell with two convex sides. The same sequence of events has been observed for lateral shoot apices as well as for principal shoot apices.

TYPE II. TRANSITION TYPE (TENTATIVE)

The second category includes a group of pteridophytes whose shoot apices exhibit *two to five apical cells* (fig. 1). These initials usually prismatic in form, not pyramidal, divide anticlinally and occasionally periclinally. The new cell walls lie parallel to the side walls and the sub-surface end wall of prismatic cells. No new cell walls form near the exposed surface of the cells. For this reason the apical cells remain at the summit of the shoot apex. Subsequently the new cells divided anticlinally and periclinally. From these cells the tissues of the shoot differentiate.

A great deal of care must be exercised in interpreting the structure of shoot apices of the pteridophytes in which one or more apical initials are thought to exist. Williams (1931) and others have clearly shown that a median longisection may reveal one large apical cell appearing triangular in form while in a median longisection taken at right angles to the first, one may see two narrow, more or less prismatic apical cells. In addition, if shoot apices in the early stages of branching are observed, 2, 4, or more cells representing two sets of adjacent apical initials of two incipient branches may be seen. In either of the cases cited above, a misconception of the structure of the shoot apex might be obtained.

The comments of authors and their illustrations, at least in some cases, indicate that well defined apical cells do not exist. Instead the shoot apex is covered with an unstratified row of periclinally and anticlinally dividing cells some of which nearest the summit may be slightly larger than those on the flanks. It might be expected, therefore, that species segregated into this category on the basis of present evidence may, later, upon re-examination of the evidence, be placed under Type III.

Plants which have been reported to exhibit this type of shoot apex organization are listed below.

Selaginella wallichii	2 apical initial cells (four-sided pyramids)	(Strasburger, 1873)
S. grandis	2 apical initial cells	(Williams, 1931)
Marattia fraxinea	4 or more apical initial cells	(Bower, 1889)

Selaginella kraussiana (Wand, 1914) exhibits both Type I and Type II organization in the same plant and therefore, in a sense, represents a transitional form. The main shoot reportedly has two four-sided pyramidal cells at the shoot apex while the side shoots have only one three-sided pyramidal cell at the apex.

TYPE III. LYCOPODIUM TYPE

The species (pteridophytes, with one exception) belonging to this category have shoot apices which exhibit three zones (fig. 1). Zone 1, the surface meristem, is an *unstratified* surface cloak of cells dividing by anticlinal, periclinal, and slanting walls. The cells differ in size, shape, and dimensions. In a median longisection the surface cap of cells appears very irregular due to the fact that some cells are short, just having divided periclinally; some are triangular, the result of a spindle oriented obliquely; some are long and slender; and some are long and broad. In many[2] species, periclinal divisions are more frequent than anticlinal or oblique divisions. This seems to be the principal factor responsible for the extreme irregularity of the outer row of cells. The cells are not uniform and do not form a clearly stratified layer such as will be found in Types IV to VII.

No apical cell or *distinct* group of initial cells are distinguishable from the other cells of the surface cloak. Foster (1939a) as well as Härtel (1938) have chosen to refer to a central terminal group of cells in shoot apices of seedlings (but not in older plants) of *Cycas revoluta* and in old plants of *Lycopodium* spp. as "apical initials." The descriptions and photomicrographs of both authors clearly indicate that these "apical initials" of the surface cloak exhibit no differences in size, shape, and plane of cell division from those of other cells of the surface cloak. Periclinal divisions occur throughout the surface cloak of cells. It seems to the author that these "apical initials" differing from other cells of the surface cloak in one respect only, i.e., location, do not constitute a separate and distinguishable growth zone. The group of cells might logically be termed *apical* because of its location. The term "apical initials," however, would seem to imply (1) a group of cells showing a distinctive "fixed or regular scheme of segmentation" and (2) a group of cells ultimately responsible for the initiation of all cells of the shoot apex. The "apical initials" of *Cycas revoluta* seedlings (Foster, 1939a) and *Lycopodium* spp. old plants (Hartel, 1938) are not distinctly different from any other cells of the surface cloak in either respect. Foster (1940) admittedly found no evidence for a group of "apical initials" in shoot apices of older plants of *Cycas revoluta*.

The cells of Zone 1 act as the initials of (1) the epidermis, (2) zone 2, and (3) indirectly as initials of all other tissues of the shoot apex. Zone 1 is of paramount importance in determining the growth of the shoot as a whole.

Under the central portion of the surface meristem lies Zone 2, the *central meristem*. At the irregular and indefinite junction of the two zones, periclinal derivatives lie in vertical tiers under the surface cells. The basal cells of the tiers divide by periclinal, anticlinal, and slanting walls resulting in a mass of irregularly arranged cells. Occasionally some of these cells and their derivatives divide transversely a number of times resulting in short chains of cells as might be expected in a rib meristem. Most of the enlarging cells of the zone become highly vacuolate and account for rapid growth in diameter very close to the shoot tip. Cells of Zone 2 differentiate into the central tissues of the shoot, i.e., in *Cycas revoluta*, the pith; in *Lycopodium*, the stele.

Zone 3, the peripheral meristem flanks the central meristem. It derives new cells from three sources (1) from periclinally dividing surface cells on the flanks of the apex, (2) from anticlinal, periclinal, and oblique divisions of cells within the zone itself, and (3) in some instances (as in *Cycas revoluta*) from anticlinal

[2]The careful investigations of West and Takeda (1915) on several species of *Isoetes* indicates that cells of the surface cloak divide periclinally only occasionally, while in the underlying mass of cells, periclinal and anticlinal divisions occur in equal numbers.

and oblique cell divisions at the periphery of Zone 2. The cells of the peripheral meristem are ordinarily smaller than those of Zone 2 and are often elongate. Out of the cells of the zone differentiate the cortex and, in *Cycas revoluta*, the procambium and leaf primordia. In *Lycopodium* and *Selaginella*, leaf primordia originate in Zone 1.

Some of the plants whose shoot apices exhibit Type III organization are the following:

Lycopodium selago	(Cramer, 1855; Strasburger, 1872; Härtel, 1938)
L. lucidulum	(Turner, 1924)
L. complanatum	(Härtel, 1938)
L. alpinum	" "
L. annotinum	" "
Selaginella arborescens	(de Bary, 1884)
S. pervillei	" "
S. spinulosa	(Bruchmann, 1897)
S. lyallii	(Bruchmann, 1909a, 1910)
S. preissiana	" " "
S. lepidophylla	(Wand, 1914)
S. uncinata	" "
S. oregana	(Smith, 1938)
Isoetes duriaei	(Hegelmaier, 1874)
I. japonica	(West and Takeda, 1915)
I. lacustris	(West and Takeda, 1915; Bruchmann, 1874; Farmer, 1890–91)
I. hystrix	(West and Takeda, 1915)
I. velata	(West and Takeda, 1915; Hegelmaier, 1874)
Phylloglossum sp.	(Bower, 1886)
Macroglossum alidae	(Campbell, 1914)
Cycas revoluta	(Foster, 1939a, 1940)

West and Takeda (1915) assert that even the youngest plants of the *Isoetes* species which they have studied have a shoot apex organization like Type III. Bruchmann (1874) and Farmer (1890–91) working with *Isoetes lacustris* and Hegelmaier (1874) working with *Isoetes velata* and *Isoetes duriaei* reached the same conclusion. These data are in disagreement with the earlier works of Hofmeister (1862) on *Isoetes lacustris* in which he reported a single tetrahedral cell. The age of the plant examined by Hofmeister was not stated. Scott and Hill (1900) working with young specimens of *Isoetes hystrix* reported finding a single prismatic several-sided apical cell which was somewhat larger and longer than other unstratified cells of the surface layer. For shoot apices of older plants they reported two somewhat larger apical cells. In the oldest specimens they found an unstratified layer of many cells (Type III).

A great deal of discussion and research has centered about the problem of shoot apex organization of the species belonging to the Marattiaceae. Many differences of opinion held by various workers have now been resolved by investigators who have studied plants of the same species at different ages. It now appears that a single apical cell is usually found in the shoot apex of the young sporeling. In somewhat older plants, this apical cell is no longer evident but instead, a group of equivalent initial cells or an unstratified layer of cells becomes apparent. In *Danaea alata*, *Danaea nodosa*, and *Kaulfussia aesculifolia* (West, 1917) the young sporeling has a single three-sided pyramidal or prismatic apical cell, the older sporeling has a single four-sided more or less prismatic apical cell while rapidly growing older stems exhibit an unstratified layer of many cells dividing both anticlinally and periclinally (Type III). The same series of events occurs in *Danaea simplicifolia* (Brebner, 1896, 1901, 1902) except that the single apical cell of the

young sporeling is four-sided. A three-sided prismatic or a wedge-shaped cell occurs in the shoot apex of the young sporeling of *Angiopteris evecta* (Bower, 1885, 1889; Farmer and Hill, 1902) while an unstratified layer of equivalent initials appears in the shoot apex of rapidly growing older plants. Jonkman (1896, 1897) reported finding an unstratified layer of cells over the shoot apex surfaces of very young and older sporophytes of both *Angiopteris* and *Marattia* species. Charles (1911) found a single apical initial cell (at first three-sided and pyramidal, then four-sided and prismatic) in the sporeling shoot apex of *Marattia alata* while an unstratified surface layer of cells covered the shoot apices of older plants (Type III).

Some species of the genus *Selaginella* exhibit variations worthy of note. Burchmann (1909b) described the young shoot apex of *Selaginella poulteri* as having a three-sided pyramidal cell (Type I) while shoot apices of older branches have several initial cells arranged in an unstratified layer (Type II or III). According to Wand (1914) *Selaginella gracilis* exhibits Type III organization in the main shoot apices. Side branches of the same plants at first have two four-sided cells at the summit of the shoot apex and later have one apical cell with two convex sides.

At the shoot apex of *Lycopodium phlegmaria*, Treub (1886) found one prismatic initial cell in very young plantlets, two in older plantlets, and his figures illustrate an unstratified layer of six to twelve cells (Type III) in still older plants.

TYPE IV. GINKGO TYPE

The Type IV shoot apex organization is characterized by five zones (fig. 1). Zone 1, the *surface meristem*, consists of a rather well defined surface layer of cells or, as in *Dioon edule* (Foster, 1941b), *Microcycas calocoma* (Foster, 1943), *Zamia* spp. (Johnson, 1939), and others, a surface layer of cells and their periclinal derivatives arranged in more or less well defined vertical tiers. In *Zamia*, additional tiers may be initiated by the anticlinal or oblique division of any cell of the tier. When this occurs, the regularity of the tier pattern is somewhat altered. Cells of the surface layer may be more or less the same size, or as in *Ginkgo* and *Sequoia*, there may be a small number of larger periclinally dividing "apical initial cells" at the summit of the apex. Since most of the cell divisions are anticlinal, the layer in most instances appears more or less discrete. Some periclinal divisions do occur in both the summit and flank cells of the surface layer. Although they are relatively infrequent, they are probably more abundant at the summit in the group of "apical initial cells." The surface layer of cells therefore not only perpetuates itself but contributes cells to the zones lying beneath. Because of these periclinal divisions, the surface row of cells should not be termed a protoderm.

Zone 2, a group of *central mother cells*, lies in a central position directly below Zone 1 and lacks the characteristics associated with meristems of spermatophytes. The irregularly arranged polygonal cells of the zone are larger, sometimes very much larger, than any of the surrounding cells. They may have huge nuclei, much-vacuolated cytoplasm, and often much-thickened walls, particularly at the cell corners. It may be inferred from their large size that cell division is relatively infrequent, cell enlargement being the more characteristic process. This group of cells, lenticular in *Ginkgo* and others, or funnel-shaped in *Microcycas* and others, is maintained during shoot elongation (1) by periclinal divisions and subsequent enlargement of the innermost cells of Zone 1 and (2) by infrequent cell divisions which occur in diverse planes in the central mother cells. Zone 2 is primarily a region of increase in volume.

Zone 3, a *cambium-like zone* of tabular cells, forms a cup-shaped transition region between Zone 2 and the zones lying below. The rather narrow zone is characterized by relatively frequent cell divisions in planes at right angles to radii centering at the summit of the apex. Some cell divisions occur parallel to the radii. The zone, therefore, perpetuates itself in thickness and diameter and contributes cells to the zones lying beneath it.

Zone 4, the *central meristem*, constituted of pith initials or rib meristem or both, lies directly below the central portion of the cup-shaped zone of cabmium-like cells. The zone consists of (1) a large number of cells which are produced by continued transverse divisions and (2) a smaller number of cells dividing in other planes. As a result, the cells are more frequently arranged in continuous rows or several-celled chains which are tapered at both ends. Cell elongation and enlargement are rapid. Cell divisions in Zone 3 and within Zone 4 itself perpetuate the meristem. Pith differentiates from the rib meristem or directly from pith initials.

Zone 5, the *peripheral meristem*, forms a cylinder lying subjacent to the edge of the cup-shaped or funnel-shaped Zone 3. The meristem is perpetuated by cells contributed by Zones 1 and 3 and by periclinal and anticlinal cell divisions within the peripheral meristem. The epidermis, cortex, foliar primordia, procambial ring and in some cases, as in *Zamia* and *Microcycas*, the outer pith cells differentiate from the cells of Zone 5.

It will be seen from the foregoing that Type IV differs in a very important manner from Types I, II, and III. Even though cells of the surface layer divide periclinally in Type IV shoot apices, they are relatively indirect in their contribution to extension growth of the central and peripheral meristems while periclinally dividing surface cells of Types I, II, and III are of prime and direct importance in this respect.

Some of the species having Type IV shoot apex organization are listed below.

Ginkgo biloba	(Foster, 1938)
Zamia integrifolia	(Johnson, 1939)
Z. silvicola	" "
Z. umbrosa	" "
Z. umbrosa	" "
Z. latifoliata	(Johnson, 1945)
Dioon edule	(Foster, 1941b)
Microcycas calocoma	(Foster, 1943)
Encephalartos villosus	(Johnson, 1944)
E. woodii	" "
E. horridus	" "
E. lehmanii	" "
E. frederici-guilielmi	" "
E. altensteinii	" "
Bowenia serrulata	" "
Macrozamia spiralis	" "
M. corallipes	" "
Sequoia sempervirens[3]	(Sterling, 1945; Cross, 1943b)
Pseudotsuga taxifolia	(Allen, 1947; Sterling, 1946)

TYPE V. ABIES-CRYPTOMERIA TYPE

Shoot apices in this category exhibit four growth zones (fig. 1). Zone 1, the *surface meristem*, is a well defined layer of cells apparently uniform in thickness. Anticlinal divisions predominate in the layer but periclinal divisions occur more than occasionally. Periclinal divisions may (1) be limited to or near the summit, except at loci of leaf and bud initiation (refer to list B below) or (2) may occur at any locus in the surface layer (refer to list A below). It seems to the author that periclinally dividing cells located only at the summit in the surface layer may justifiably be referred to as "apical initials." This has been done by Cross (1939, 1941, 1942, 1943a, 1943b). However, the application of the term "apical initials"

[3]Type IV organization is present in apices of leading shoots while Type V organization occurs in apices of lateral branches (Sterling, 1945).

to the central cells of the surface layer appears indefensible if any or all of the morphologically similar cells of the surface layer may be expected to contribute to underlying zones. Some workers have done this. In either case, periclinal divisions appear to be either infrequent or quickly followed by (1) cell enlargement or (2) anticlinal cell divisions. Evidence for this statement is the stratified appearance of the surface layer. The periclinally dividing cells contribute to Zone 2 and thus help to perpetuate it. Frequent anticlinal divisions occur in the surface layer both at the summit and along the flanks and account for the extension growth of the cell layer destined to differentiate into epidermis. While the cells of the surface layer may vary greatly in size, reports by early workers of an "apical cell" have not been confirmed by recent investigators.

It should be understood that periclinal division spindles or evidence of periclinal divisions are not always found in the surface layer of every median section of comparable shoot apices of each individual plant. However, the percentage of apices exhibiting the phenomenon is sufficiently high to eliminate the probability that the periclinal divisions are rare or chance occurrences, except possibly in *Ephedra*, *Gnetum*, and the permanent shoots of *Taxodium*. There is some evidence to support the claim that periclinal divisions occur in the surface layer of shoot apices more frequently at the time of elongation of the shoot (Gifford, 1943; Kemp, 1943).

In Zone 2, a group of *sub-apical initials*, vertical and oblique divisions occur but horizontal divisions are probably more common. The cells may be few in number (in small apices) and may be arranged irregularly or in short tiers. They are mostly larger but less vacuolate than the neighboring cells. The zone is not clearly demarcated in all apices. Zone 2 is perpetuated not only by internal cell divisions but by periclinal divisions in the central cells of the surface meristem. Cell divisions on the periphery of the zone account for growth in length of Zone 4, while basal derivatives of the zone contribute to the growth in length of Zone 3.

Zone 3, the *central meristem*, differentiates directly from the sub-apical initials, there being no intervening zone of cambium-like cells. Cells of the central meristem divide most frequently in a transverse plane and often are arranged in short tapered chains and irregular vertical rows. Cells thus formed, as well as those contributed by transverse divisions of the central marginal cells of Zone 2, account for growth in length of the rib meristem. The highly vacuolate, enlarging cells of the rib meristem differentiate into pith.

Zone 4, the *peripheral meristem*, forms a cylinder of elongating and dividing cells surrounding Zone 3. Divisions occur in various planes but the cells often appear to be arranged in ill-defined layers due to a higher frequency of anticlinal (with reference to the flanks) divisions. The cells later differentiate into procambial and cortical tissues and are responsible for initiation of lateral organs. In some species new cells are contributed to the zone as the result of periclinal divisions along the flanks of the surface meristem. In some species Zones 3 and 4 appear quite distinct, while in others (as in *Cunninghamia*) derivatives of marginal cells of the rib meristem augment the peripheral meristem zone.

Species having Type V shoot apex organization are listed below.

A. Periclinal divisions occur at the summit and along the flanks in the surface layer.

Pinus canadensis	(Groom, 1885)
P. sylvestris	" "
P. montana	(Korody, 1937)
Abies pectinata	(Groom, 1885)
A. alba	(Koch, 1891)
A. concolor	(Korody, 1937)
A. venusta	(Foster, 1941a)

Taxus baccata	(Koch, 1891)
T. canadensis	" "
Picea excelsa	(Koch, 1891; Korody, 1937)
P. orientalis	(Koch, 1891)
Torreya californica	(Kemp, 1943)
Metasequoia glyptrostroboides	(Sterling, 1949a)
Gnetum gnemon[4]	(Johnson, 1950)

B. Periclinal divisions in the surface layer occur at the summit only.

Ephedra campylopoda	(Strasburger, 1872)
E. altissima	(Koch, 1891; Gifford, 1943)
Cephalotaxus pedunculata[5]	(Koch, 1891)
Juniperus communis[5]	" "
Cedrus libani[5]	" "
Larix decidua[5]	" "
Tsuga canadensis[5]	" "
Pinus strobus[5]	" "
Taxodium distichum[6]	(Cross, 1939)
Cryptomeria japonica	(Cross, 1941)
Cunninghamia lanceolata	(Cross, 1942)
Taiwania cryptomerioides	(Cross, 1943a)
Sequoia gigantea	(Cross, 1943b)
Athrotaxis selaginoides	(Cross, 1943a)

The reader will note that *Sequoia sempervirens* was listed among those plants exhibiting Type IV shoot apex organization while *Sequoia gigantea* has been described as having Type V shoot apex organization. The two types differ principally in the presence (Type IV) or absence (Type V) of a cambium-like zone. It has been shown for *Chrysanthemum* (Popham and Chan, 1950) that the presence of a cambium-like zone occurs in the mid-phase and is absent in the late-phase of the plastochrone. One might speculate therefore that a re-examination of *Sequoia gigantea* shoot apices would yield similar information. Sterling (1945) suggested another possible explanation for this incongruity in his statement that "Cross' description of the leading shoot apex of *Sequoia* (*gigantea*) seems to correspond to the writer's observations on the apices of lateral branches."

TYPE VI. THE OPUNTIA TYPE

The Opuntia Type of shoot apex organization, occurring in angiosperms only, consists of 5 zones (fig. 1). Zone 1, the *mantle*, forms a cap of one or more discrete layers of cells over the summit. In at least the surface layer, cell divisions are of one type only—anticlinal. If more than one layer of cells is present, anticlinal divisions occur exclusively or predominantly in them. In species having a several-layered mantle, successive underlying layers often exhibit a progression from exclusively anticlinal divisions in the surface layer or layers toward more frequent periclinal divisions (Popham and Chan, 1950). In the author's opinion, the term tunica, if used, should refer only to those surface layers in which *only* anticlinal

[4]Periclinal divisions in the surface layer of cells are apparently located on the flanks of the apex only, above the position of leaf initiation.

[5]Although Koch's descriptions of the shoot apices of these species are not at all clear, it seems reasonably certain that the species should be listed as having Type V organization. Koch is vague as to whether periclinal divisions occur at the summit in the surface layer or both at the summit and along the flanks. Shoot apices of these species should certainly be re-investigated.

[6]Type V organization is present in shoot apices of most deciduous shoots while Type VII organization occurs in the primordial stages of all shoots and during the expansion phases of most permanent shoots (Cross, 1939).

divisions occur (Popham and Chan, 1950). The term will be so used in this paper. The tunica, therefore, perpetuates (1) itself, (2) the epidermis of the shoot, and (3) may, if more than one layer of tunica is present, contribute to the zone of cambium-like cells (Zone 3). The tunica is an independent histogen only when it consists solely of one layer of cells. The cells of the surface layer, when viewed in longisection, are very nearly equal in thickness although the summit cells of the layer may be vacuolate, very much wider, and somewhat more irregular in thickness than the cells on the flanks. This combination of characteristics suggests the probability that cell divisions are less frequent at the summit than on the flanks.

Zone 2, the *central mother cells*, is composed of a relatively small number of large, closely appressed, irregularly shaped, often conspicuously vacuolate cells. Cell walls in some species are quite thick, particularly at the corners. Cell divisions may occur in many different planes, but at relatively infrequent intervals. Since the mantle (Zone 1) may include some sub-surface layers of cells in which periclinal divisions occur less or more frequently, Zone 2 may receive cellular contributions from the innermost of the mantle layers. In species such as *Trichocereus* and *Opuntia* in which only one mantle layer (a tunica layer) occurs, Zone 2 perpetuates itself independently and is truly a zone of initiation for the entire shoot, except the epidermis. Transverse and obliquely dividing cells along the inner boundary of the zone contribute new cells to Zone 3.

Zone 3, the *cambium-like zone*, is more or less cup-shaped, underlies Zone 2, and extends to the perimeter of the shoot tip. Its cells are meristematic, their protoplasm is dense, and their shape is reminiscent of stelar cambium cells. Most cell divisions are in planes at right angles to radii centering at the summit of the apex. The cells are frequently elongated paralleling the arc of the zone New cells are contributed to Zone 3 by Zone 2 and in some species in which the cambium-like zone interrupts the surface layer (as in *Chrysanthemum*), by both Zones 1 and 2. The zone may be only a few tiers of cells thick and therefore indistinct, or it may be well defined, 8–10 cells deep, (as in *Trichocereus*). Cells formed in Zone 3 lie in longitudinal rows and account for growth in length of Zones 4 and 5.

Zone 4, the *central meristem*, originates from transverse divisions in the central cells of the zone of cambium-like cells (Zone 3). Transverse divisions predominate in the zone, resulting in the formation of tapering strands of mitotically related cells and irregular tiers of cells. Newly formed cells elongate and enlarge rapidly as evidenced by their large vacuoles. The cells differentiate into pith only (as in *Opuntia* and *Chrysanthemum*) or into pith and medullary procambial strands (as in *Phoenix* and *Trichocereus*).

Zone 5, the *peripheral meristem*, forms a cylinder lying within the protoderm and around the central core of cells (Zone 4). Cells of the zone are usually much smaller than those of Zone 4 and are mostly elongated axially. They divide both anticlinally and periclinally. Transverse divisions predominate resulting in a tissue whose cells appear somewhat stratified. Vacuolation of most cells, especially those lying closest to Zone 3, is slight. The zone gives rise to the cortex, foliar organs, and all (as in *Opuntia* and *Chrysanthemum*) or a part (as in *Phoenix* and *Trichocereus*) of the procambial tissue.

Some of the species exhibiting Type VI shoot apex organization are the following.

	Number of Mantle Layers	
Livistona chinensis	2	(Helm, 1936)
Phoenix canariensis	1	(Ball, 1941)
P. dactylifera	1	(Ball, 1941)
Trichocereus spachianus	1	(Boke, 1941)
Opuntia cylindrica	1	(Boke, 1941)
Bellis perennis	2	(Philipson, 1946)

Liriodendron tulipifera	2–3	(Millington and Gunckel, 1950)
Chrysanthemum morifolium[7]	2–5	(Popham and Chan, 1950)

TYPE VII. THE USUAL ANGIOSPERM TYPE

The Usual Angiosperm Type of shoot apex organization, occurring in angiosperms only, with two doubtful exceptions, is characterized by 4 zones (fig. 1). Zone 1, the *mantle*, consists of at least one discrete, independent, and self-perpetuating surface layer whose cells divide *exclusively* in anticlinal planes. The mantle may consist (1) solely of the one tunica layer or (2) of one (usually), two, or more tunica layers plus one or more sub-tunica layers of cells in which periclinal and occasionally oblique divisions occur, but in which most divisions are anticlinal. The total number of cell layers in the mantle varies from one to nine. Shoot apices of angiosperms reportedly exhibiting isolated instances of periclinal divisions in the surface layer such as *Zea mays* (Sharman, 1940), *Agropyron repens* (Sharman, 1943), *Chlorogalum pomeridianum* (Sterling, 1944), *Ruppia maritima* and *Cymodocea nodosa* (Pottier, 1934), *Triticum vulgare* (Rösler, 1928), and *Avena sativa* (Kliem, 1937) are for the present considered unusual irregularities and the species, for which sufficient additional data are available, are included in Type VII. If it can be demonstrated that periclinal divisions occur in the surface layer with any degree of regularity, the apex should be classified as Type V. Periclinal divisions when present in cells of the inner mantle layers result in cellular additions to Zone 2. In median longisections, cells of the surface tunica layer (and usually in other tunica layers if present) appear to be uniform in thickness even though those at the summit may be larger (wider) than those on the flanks.

Reeve's (1948) suggestion that generally the number of mantle layers observed in a shoot apex is less following leaf initiation than immediately preceeding leaf initiation has been supported by Sterling (1949b) and Cross (1937). This proposition has been challenged by Popham and Chan (1950), Millington and Gunckel (1950), and others.

Zone 2, the *sub-apical initials*, is composed of a self-perpetuating group of irregularly shaped cells which may divide in various planes. The rate of cell division is relatively slow in the lenticular zone of sub-apical initials when compared with the rate in the surrounding zones. The cells of Zone 2, located at the summit of the apex back of the mantle, are usually larger, often highly vacuolate, and therefore lighter staining, than surrounding cells. Strictly speaking, periclinally dividing central cells of inner mantle layers should also be included as sub-apical initials. Sub-apical initials of *lateral* shoots in *Succisa* (Philipson, 1947) apices are exceptional in that they apparently are smaller, not larger, than surrounding cells. In some species (as in *Sinocalamus beecheyana*) cell walls are thickened, particularly at the corners. The zone may consist of many cells in the larger apices or as few as one single cell in the narrow apices of slender grasses (Sharman, 1945). Cross (1937) reported that "the initials of *Viburnum rufidulum* gradually lose their identity and often may not be seen at all prior to the inititaion of a pair of leaves." A condition, first reported by Ball (1949) for *Lupinus albus* in which sub-apical initial cells divide forming individual groups of cells surrounded by the original cell wall, is apparently an infrequently encountered phenomenon of Zone 2. Since the zone is the forerunner of Zones 3 and 4 it is in many species the ultimate origin of all tissues of the shoot apex except the epidermis and its derivatives.

Zone 3, the *central meristem*, lies in the central part of the apex immediately below Zone 2. The zone enlarges by (1) contributions of cells from Zone 2, (2) by divisions (mostly transverse) of central meristem cells themselves, and (3) by cell enlargement and cell elongation. Due to successive transverse divisions of central

[7]The Opuntia Type of organization is present during the early and mid phases of the plastochrone while the Usual Angiosperm Type of organization (Type VII) is apparent in the late phase of the plastochrone.

meristem cells, tapering files and irregular tiers result in the formation of a rib meristem. The rib meristem is not a constant feature of the zone in all species but is usually present in larger apices. Cells of the zone differentiate into pith or into pith and medullary procambial strands. The cells are usually highly vacuolated and therefore light-staining. Primary pit fields are commonly found on the cell walls.

Zone 4, the *peripheral meristem*, forms a cylinder lying beneath the protoderm and surrounding Zone 3. It grows by means of cells contributed to it (1) by Zone 1 in species having more than one mantle layer, (2) by Zone 2 and (3) by cell divisions, mostly transverse, which occur in the cells of the meristem itself. Since anticlinal (with reference to the flanks) divisions are most common, the relatively small cells of the zone become somewhat stratified. Vacuolation of the cells is usually inconspicuous, and consequently the cells stain more deeply than those in Zone 2. In most species, some cells of the zone become involved in foliar initiation while others differentiate into cortex and procambial strands.

Zones 3 and 4 are sometimes (1) indistinct as separate entities or (2) non-existant, especially in the shoot apices of monocots, particularly so in the small shoot apices of the Gramineae. Zone 4 may be reduced to a single layer of cells.

Some of the species exhibiting a Type VII zonation pattern are the following.

	Number of Mantle Layers	
Araucaria brasiliana	3	(Strasburger, 1872)
Sciadopitys verticillata	2	" "
Elodea canadensis	2	(Herrig, 1915)
E. densa	2	" "
Hippuris vulgaris	4–6	(Groom, 1885; Herrig, 1915; Louis, 1935)
Dactylis glomerata	1–2	(Bugnon, 1924)
Melica altissima	1–2	" "
Secale cereale	1	(Rösler, 1928)
Triticum vulgare	1	" "
Phyllostachys nigra	3	(Porterfield, 1929–30)
Ruppia maritima	2	(Pottier, 1934)
Cymodocea nodosa	2	" "
Posidonia ponticum	2	" "
Avena sativa	1	(Kliem, 1937; Hamilton, 1948)
Washingtonia filifera	2	(Ball, 1941)
Trachycarpus excelsa	2	" "
Zea mays	1	(Sharman, 1942)
Sinocalamus beecheyana	1–3	(Hsü, 1944)
Agropyron repens	2	(Sharman, 1945)
Myriophyllum spicatum	2	(Groom, 1885)
Ceratophyllum demersum	2	" "
Utricularia minor	2	" "
Galium rubioides	2	(Herrig, 1915)
Honckenya peploides	3	" "
Oenothera albiflava	2–3	(Krumbholz, 1925)
Pelargonium zonale	2–4	" "
Plectranthus fruticosus	2–3	(Schwarz, 1927)
Ligustrum vulgare	3–4	" "
Hypericum uralum	4	(Zimmerman, 1928)
Carya cordiformis	2	(Langdon, 1931)
C. buckleyi	2–4	(Foster, 1935)
Syringa vulgaris	2	(Louis, 1935; Schmidt, 1924)

Centaurium umbellatum	2	(Halmai, 1935)
Morus alba	2	(Cross, 1936)
Rhododendron ponticum	2–4	(Foster, 1937)
Viburnum rufidulum	4	(Cross, 1937)
Lathyrus latifolius	1–3	(Schüepp, 1938)
Geum urbanum	2 (?)	(Grégoire, 1938)
Aconitum napellus	1 (?)	" "
Frasera carolinensis	2	(McCoy, 1940)
Acacia longifolia and other spp.	3–5	(Boke, 1940)
Amygdalus communis	4	(Brooks, 1940)
Vinca rosea	2–4	(Cross and Johnson, 1941; Boke, 1947)
Datura stramonium	3	(Satina and Blakeslee, 1941)
Heracleum sphondylium[8]	8–9	(Majumdar, 1942)
Garrya elliptica	1–3	(Reeve, 1942)
Rubus idaeus	3	(Engard, 1944)
R. pubescens	3	" "
R. rosaefolius	3	" "
R. hawaiensis	2	" "
Descurainia pinnata	2–3	(Dittmer and Spensley, 1947)
Valeriana officinalis	1	(Philipson, 1947)
Succisa pratensis	2	" "
Dipsacus fullonum	2	" "
Galinsoga parviflora	2	(Lawalrée, 1948)
Chrysanthemum leucanthemum	2	" "
Myrica californica	1–3	(Reeve, 1948)
Cornus californica	1–3	" "
C. nuttalii	1–3	" "
C. rostrata	1–3	" "
Castanopsis californica	3–4	" "
Lithocarpus californica	3–4	" "
Quercus kelloggii	3–4	" "
Salix laevigata	2	" "
Ananas comosus	1 (?)	(Krauss, 1948)
Lupinus albus	1–2	(Ball, 1949)
Dianthera americana	2–3	(Sterling, 1949b)
Glycine max	2	(Sun, 1950)

DISCUSSION

Many authors have pointed out small differences that exist between shoot apices of various genera, between shoot apices of the same species, and between zones in a single apex, but the equally important consideration of similarities has been neglected. A student of plant anatomy can find only a series of isolated, detailed, and seemingly unrelated descriptions of shoot apices in the literature. If useful comparisons are to be made and if there is to be an intelligent selection of research materials in the future, an over-all pattern of what is known must first be perceived. The author has attempted, by neglecting minor details of difference, to outline such a pattern (table 1).

If it is true that in most individuals the gene complement of all cells of vegetative organs is identical, it appears fairly certain that some of the types of shoot apex organization described are more positively determined by heredity in some species than in others. In some species gene control is sufficiently unstable and the heredi-

[8] In spite of references to a cambium-like zone in the shoot apex of *Heracleum* by others, the present author could not find in Majumdar's paper a satisfactory description confirming the existence of such a zone.

tary limits are sufficiently broad so as to occasionally allow external and internal environmental factors to exert the determining influence. *Chrysanthemum morifolium*, *Zea mays* and several other monocots, *Taxodium distichum*, *Selaginella martensii*, *S. kraussiana*, *S. poulteri*, *S. gracilis*, *Lycopodium phlegmaria*, *Isoetes hystrix*, *Danaea alata*, *D. nodosa*, *D. simplicifolia*, *Kaulfussia aesculifolia*, *Angiopteris evecta*, and *Marattia alata*, are examples of plants in which the physiological state within the shoot apex may be sufficiently altered by the environment to result in different types of shoot apex zonation (1) in different apices on the same plant or (2) in different stages of ontogeny in the same shoot apex. These variations have been noted previously in this paper and will therefore not be described again. Differences in contour of shoot apices of the same plant, differences in dimensions of the shoot during different stages in the plastochrone, and differences in the number of mantle layers (if present) of shoot apices of the same plant have been noted by many authors (Schmidt, 1924; Louis, 1935; Cross and Johnson, 1941;

TABLE 1

A summary of the distinguishing features of the principal types of vegetative shoot apex organization in vascular plants.

Characteristic Features	Type I Fern	Type II Transition	Type III Lycopodium	Type IV Ginkgo	Type V Abies-Cryptomeria	Type VI Opuntia	Type VII Usual Angiosperm
Single Apical Cell	*	....	....	....	....	....	....
2–5 Apical Cells	....	*	....	....	....	....	....
Surface Meristem (S) (both anti- and periclinical divisions in surface row)	....	....	*	*	*	....	....
Mantle (M) (anticlinal divisions only in surface layer(s))	....	....	....	....	....	*	*
Central Mother Cells (MO)	....	....	....	*	....	*	....
Cambium-Like Zone (C)	....	....	....	*	....	*	....
Sub-Apical Initials (SA)	....	....	....	....	*	....	*
Central Meristem (CM)	....	....	*	*	*	*	*
Peripheral Meristem (P)	....	....	*	*	*	*	*

Engard, 1944; Reeve, 1948; Popham and Chan, 1950; and others). Complexity of the zonal pattern or volume of zones or both may be considerably reduced in the early phase of the plastochrone (time of minimal size of the shoot apex) in *Torreya californica* (Kemp, 1943), *Abies concolor* (Korody, 1937), *Gnetum gnemon* (Johnson, 1950) and *Chrysanthemum morifolium* (Popham and Chan, 1950). These differences are probably not controlled completely by heredity.

In the light of the facts cited above, it behooves the researcher to examine many shoot apices from many locations on the same plant and on different plants of the same species, as well as shoot apices exhibiting different stages in the plastochrone before he makes any definite statements regarding the structure of the shoot apex of any particular plant.

If the reader will peruse the plant names listed for each type of shoot apex organization, little doubt can exist that heredity is an important factor in the determination of shoot apex organization and the growth pattern. It will be seen that there is a phylogenetic trend toward reduction of the number of periclinal and oblique cell divisions at the surface of the apex. The trend in the plant

kingdom appears to be from (1) a single apical cell to (2) a few apical cells to (3) many cells dividing anticlinally, periclinally, and obliquely, arranged throughout a very irregular surface row to (4) a very few cells dividing periclinally accompanied by many cells dividing anticlinally, arranged throughout a regular surface layer to (5) a very few periclinally dividing cells at the summit of the surface layer to (6) all cells of the surface layer dividing anticlinally.

It is rather disconcerting to find (1) that although a diversity of types of shoot apex organization exists, most of the species exhibit basic similarities in that there is a rather uniform development of protoderm, procambium, and ground meristem back of the apex proper and (2) that plants such as *Zea*, *Washingtonia*, and *Carya* having such dissimilar tissue organization in the older portions of the stem show a similar shoot apex structure (Type VII). From these examples and many others that could be cited, one is forced to infer that stem structure is not obviously (if at all) related to shoot apex structure.

Whether inconsistencies, such as a monocot (*Livistona*) and a composite (*Chrysanthemum*) exhibiting the same type (Type VI) of shoot apex organization, (1) are only apparent, due to inaccurate or insufficient observations or (2) are real, due to the fact that the same progression, ending in the presence of the zone of cambium-like cells, reappears in various phylogenetic lines of higher plants, remain unanswered questions.

It will be noted that no angiosperm shoot apex has been described in which periclinal divisions regularly or frequently occur in the surface layer of cells. In other words, all angiosperm apices thus far studied exhibit at least one true tunica layer (Sterling, 1944). Only two gymnosperms, (*Araucaria brasiliana* and *Sciadopitys verticillata* (Strasburger, 1872), are presumed to exhibit no periclinal divisions in the surface layer. For this reason a reinvestigation of these species is in order.

It should be emphasized that the surface cloak of cells in Type III does not present the appearance of a *regular layer*. Periclinal and oblique divisions and subsequent cell enlargement occur too frequently at irregular intervals and too extensively in the surface cloak to allow a stratified appearance. In Types IV through VII this is not the case. Even though periclinal divisions occur in the surface cloak of cells in types IV and V, they are so infrequent (and even then, in some species, they are restricted to the few summit cells of the cloak) that a definitely stratified appearance results. No periclinal divisions occur in the surface layer in Types VI and VII. These considerations are important to an understanding of growth at the shoot apex. In Types IV through VII the surface layer of cells is of little (Types IV and V) or no (Types VI and VII) importance in the elongation of the shoot except insofar as extension of the epidermis is concerned. In species having Type III shoot apex organization, the surface cloak of cells is of paramount importance in shoot elongation.

After considering the facts, it is seen that the term *tunica* if strictly defined, allowing no periclinal divisions in its layers except during leaf and bud initiation, may be used only in describing shoot apices exhibiting Types VI and VII organization. It may be applied to one or more layers of cells. There may be, however, other subjacent layers in which only *occasional* periclinal divisions occur. These layers for all practical considerations should also be thought of as contributing little to extension growth of the shoot as a whole. Since the term tunica connotes a strict usage to some workers and a loose usage, allowing few or many periclinal divisions, to others, its usefulness in accurately describing growth relations at the shoot apex is questionable. It is primarily for this reason that the term *mantle* has been used in describing zonal organizations. The mantle is thought of as including all layers at the summit of the apex in which anticlinal divisions are sufficiently frequent to result in the perpetuation of definite cell layers. The mantle therefore accounts for extension growth of its own layers primarily and only incidentally accounts for the perpetuation of underlying growth zones.

Use of the term *corpus* has been avoided because it was not found useful in presenting an accurate concept of the part played by cells underlying the "*tunica*." If the term corpus were used, it could be applied logically only to types VI and VII in which a true "tunica" is present. Therefore it would include two zones in which cell divisions are not rapid (the central mother cells and sub-apical initials), and four types of active meristems (1) stratified layers of cells underlying the tunica in many species in which divisions are mostly anticlinal, (2) the cambium-like zone, (3) the central meristem, and (4) the peripheral meristem. It seems to the author that the term corpus when used to include such a heterogeneous assemblage of growth zones is likely to convey a confused, over-simplified and erroneous concept of shoot growth, if indeed it conveys any at all.

The term *central meristem* was chosen in lieu of rib meristem since shoot apices of some species (*Ephedra altissima*, Gifford, 1943, and others) do not always exhibit pith forerunner cells in distinct longitudinal tiers or tapered filaments. In some species, such as *Heracleum*, the file (rib) meristem does not appear in the shoot apex above the last leaf primordium (Majumdar, 1945).

SUMMARY

1. Seven principal types of shoot apex organization have been described for vascular plants. The major differences and similarities are summarized in table 1. The growth patterns of each of these types are summarized in figure 1. Shoot apex Types I, II, and III have been found to exist only among the pteridophytes, with one exception (*Cycas revoluta*—Type III). Types IV and V reportedly exist only in gymnosperm shoot apices while Types VI and VII occur in shoot apices of angiosperms only, with two doubtful exceptions (*Araucaria brasiliana* and *Sciadopitys verticillata*—both Type VII).

2. Since different types of organization appear in shoot apices of the same individual plant, and since the same type of organization occurs in shoot apices of plants in different genera, it follows that differences in shoot apex organization do not necessarily cause external differences in form.

3. Since different types of organization appear in shoot apices of the same individual, species, and genus of plants, it follows that differences in shoot apex structure are seldom of taxonomic value.

4. Shoot apex organization types may be of some value in broad phylogenetic studies. The following stages mark a trend in the organization of shoot apices from lower to higher vascular plants:

a. A single apical cell.
b. A few (2–5) apical cells.
c. A surface row of many irregularly elongate cells dividing anticlinally, periclinally, and obliquely.
d. A stratified surface layer of cells, many dividing anti-clinally and few dividing periclinally, located at the summit and along the flanks of the apex.
e. A stratified surface layer of cells in which anticlinal divisions are most frequent and periclinal divisions are restricted to the summit of the apex only.
f. One or more stratified surface layers of cells in which all divisions are anticlinal.

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The Naturalists' Directory. Thirty-sixth edition. Salem, Massachusetts. $3.00.

The Naturalists' Directory was first published in 1878 and since then has appeared every two or three years. It contains the names and addresses and a list of subjects of interest to hundreds of amateur and professional Naturalists. It has been very helpful in bringing together Naturalists in all parts of the world. In addition to the list of Naturalists there is a list of Natural History Museums and Scientific Periodicals. Naturalists generally have found the Directory very helpful.

Principles of Animal Ecology. *W. C. Allee, A. E. Emerson, O. Park, T. Park, K. P. Schmidt.* W. B. Saunders Company, Philadelphia. First Edition. 1949. ix+827 pp. $14.00.

The first section of this volume contains an excellent summary of the history of the development of ecology. It is especially valuable as reference material.

The second section presents a thorough discussion and analysis of the chemical and physical conditions of the environment with special emphasis upon the interrelationships of these factors and their combined effect upon biological organisms. These are considered from the standpoint of the various media in which the organisms live and finally the biotic factors including plant and food relationships.

Animal populations and aggregations, one of the major ecological problems today, are treated in a thorough and up-to-date manner in the third section. The material covers various types of animal populations including human populations together with the mathematical concepts of population growth.

The fourth section deals with the community in all its phases including stratification, metabolism, periodism, the problem of successions and the world's major biotic areas or biomes.

The final section concerns the important and interesting problem of ecology and evolution, which is discussed in the light of genetic mutations, isolation, adaptation, and natural selection.

The principles of ecology are treated here in a thorough and well balanced manner by a group of eminent specialists in this field. The book is well written and the material carefully selected and well organized. This excellent contribution in the field of ecology should serve as an invaluable reference source for all biologists working in any phase of ecology as well as an excellent text for advanced or graduate students of ecology in obtaining some knowledge of the basic principles of this scientific field.

DWIGHT M. DELONG.

Subtropical Entomology. *Walter Ebeling.* Lithotype Process Company, San Francisco. First Edition. 1950. x+747 pp. $7.50.

Although written primarily as a textbook for students of entomology at the University of California, Los Angeles, this book has been so thoroughly done that it also serves as a comprehensive reference volume for all those interested in subtropical horticulture or in the chemical control of insects.

Following an introduction, the next two chapters of the book cover briefly the structure and biology of insects and the recognition of the principle insect orders. Except with reference to the principles of classification, insect families are not mentioned. Insect control is discussed in the next fourteen chapters. This includes not only an up-to-date discussion of insecticides and their application but also biological control, experimental techniques, and legislative control. The excellent chapters on spray oils and fumigation reflect the author's wide practical experience in those fields.

The last eleven chapters deal with the specific pests of the subtropical crops: citrus, grape, walnut, almond, pecan, fig, olive, date, avocado, and minor fruits. In this section recognition, distribution, life history, and control of each important species are considered. The excellent illustrations, many of them original photographs, which appear throughout the book are especially valuable here in aiding identification. The nearly 1050 references cited in the book are listed following the text. An author and subject index complete the volume.

The emphasis in Ebeling's book is not on general entomology, but on the principles and materials of insect control and on the practice of insect control as applied to specific pests of subtropical horticulture. In these latter fields it is a valuable reference source.

FRANK W. FISK.

USE OF THE SCAPULA AS A MEANS OF DIFFERENTIATION BETWEEN THE MEARNS' COTTON-TAIL AND THE AUSTRALIAN IMPORTED AND DOMESTIC HARE[1]

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Frequently some difficulty is encountered in distinguishing between cotton-tail rabbits, hares, and cats when skinned carcasses are offered for sale on the market. Not infrequently cats have been sold in lieu of rabbit, both in markets in Ohio and in restaurants (Ontario). In the past, cotton-tails have been sold in the markets of Ohio, but this has been prohibited by law in recent years, and the animal is protected as any other game species. More recently hares have been imported from Australia to be sold in competition with the domestic hares and rabbits.

Cats may be differentiated from rabbits and hares by size and shape of the scapula (figures 1–4) and by differences in the lower, hind-leg bones. Cats have a generally broader and larger scapula than do the hares and rabbits. Furthermore, the tibia and fibula are separate in cats, while in rabbits and hares the fibula fuses to the tibia—only about one-third of the fibula remaining as a recognizable bone.

It was decided to study the cotton-tail rabbit and the Australian imported hare in an effort to ascertain what readily accessible structure might be used to separate these two forms, and what criteria might best serve this end.

The Australian hare is reportedly derived from the Western European Hare *Lepus europaeus occidentalis*, while the Domestic Hare is derived from the same basic stock *Lepus europaeus* Pallas, and may be considered to have essentially the same origin. Through selective breeding some changes in structure have become established in the different strains of domestic hares. The cotton-tail is not, however, thus closely related to either of the above forms, but is a New World species *Sylvilagus floridanus mearnsi* (Allen).

Fourteen specimens of Australian imported hares and 22 specimens of the Mearns' cotton-tail were provided by the Ohio Division of Wildlife and a single specimen of domestic hare was contributed by Mr. Newton Deaton, of Eaton, Ohio, for this study.

A careful study of the scapula was made to determine essential differences in structure between *Lepus europaeus* and *Sylvilagus floridanus mearnsii*.

OBSERVATIONS

In general shape and outline of the scapula, the hares and cotton-tail are very similar. The axillary border is strongly produced from the neck of the scapula to the inferior angle and is even more emphasized in some of the domestic forms. The coracoid process in both the Australian hare and the cotton-tail are virtually alike, so that any seeming dissimilarity may fall within the range of individual differences. Minor differences in the medial and inferior angles as well as the vertebral border, likewise fall within the range of individual differences.

One striking and important feature along with a minor feature of the scapula are characteristic, however, and these may serve to separate the cotton-tails from the hares. The scapular spine of the Australian and domestic hares is produced laterally and somewhat ventrally from the lateral surface of the scapula, and terminates in a broadened ridge (figs. 1 and 3, A and B), while in the cotton-tail the scapular spine terminates abruptly in a narrow edge, the broadened ridge lacking, (fig. 2) and this is diagnostic for Mearns' cotton-tail.

In addition to the above characteristic, the acromion is less well-developed in the cotton-tail than in the hare, and to a limited extent, the metacromion appears to be somewhat less durable and more delicate than is the case with the hares.

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[1]Contribution from the Ohio Cooperative Wildlife Research Unit.

DISCUSSION

The above information may add but slightly to our present knowledge in the field of comparative anatomy, but it does establish an important criterion upon which to base separation of the hare and cotton-tail.

Such information may now be employed by wildlife law enforcement agents in cases of illegal possession or sale of cotton-tails, and may facilitate examination of legally sold non-game species.

In addition it may serve as a guide to detection of fradulent sale of cats in lieu of rabbits.

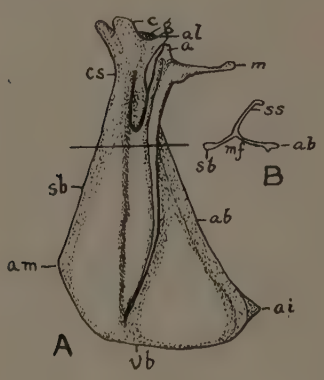


Fig. 1

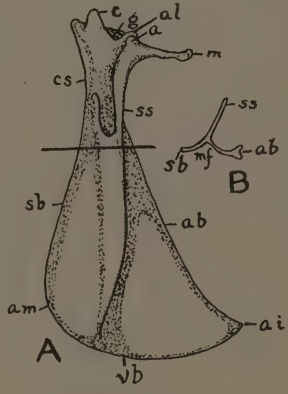
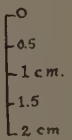


Fig. 2



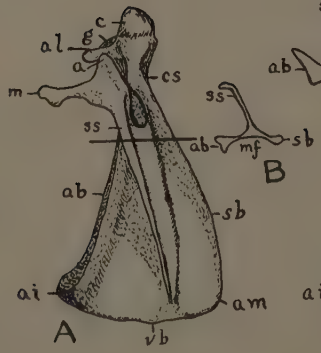


Fig. 3

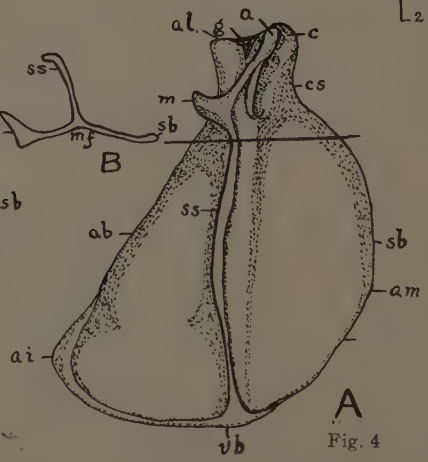


Fig. 4

FIGURE 1. Australian hare.

FIGURE 2. Cotton-tail rabbit.

FIGURE 3. Domestic hare.

FIGURE 4. Common cat.

A, lateral surface of scapula; B, cross-section through scapula at the line of A; a, acromion; ab, axillary border; ai, inferior border; al, lateral angle; am, medial angle; c, coracoid process; cs, neck of scapula; g, glenoid cavity; m, metacromion; mf, medial surface; sb, superior border; ss, scapular spine; vb, vertebral border.

RELIGION IN MOHAVE SOCIAL STRUCTURE[1]

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One of the most distinctive characteristics of the Lower Colorado River culture area is the existence of tribal organization and a strong sense of tribal unity. The Mohave tribe, one of the groups in this area, illustrates this characteristic clearly. Kroeber (1925) states that the Mohave think in tribal terms as distinguished from the village solidarity of most of the nearby Californian peoples. Devereux (1939, p. 100) also notes the "earnest and intense national feeling of the Mohave." The accounts of early explorers indicate that this tribal organization is not a recent phenomenon and provide justification for assuming that it existed prior to white contact. The existence of Mohave tribal organization is based upon a number of factors such as language, territory, mythology, ceremonial organization, clan beliefs, and external relations. The purpose of this paper, which is written in the ethnological present, is to describe the way religious beliefs contribute to the existence of a strong sense of tribal solidarity.

The Mohave consist of about 2,000 to 2,500 people living in the valley of the Colorado river near the intersection of the present-day boundaries of Nevada, Arizona, and California. The people are scattered throughout the valley according to a pattern similar to the open country neighborhoods found in modern United States rural areas. Subsistence is derived from agriculture, fishing, gathering, and hunting. Agriculture is made possible by the flooding of the river which inundates a narrow plain and provides ample moisture for raising crops in a manner reminiscent of the ancient Egyptians who depended upon the overflow of the Nile. Large annual harvests of mesquite and screw beans also form an important part of the Mohave diet. Fishing is important during several seasons; hunting is of minor importance during the entire year. According to the best possible evaluation of the aboriginal situation, Mohave subsistence is quite secure, probably more so than for almost all of the neighboring tribes not living in the valley.

The origin myth is one of the most important aspects of Mohave religion. The scientist recognizes mythology as *one* of the important sources of tribal morale but to a Mohave mythology furnishes *the* definitive statement of his position in the tribe and in the universe as a whole. The origin myth provides the answer to all questions concerning affiliation and orientation, far outweighing any other considerations in the minds of the Mohave themselves. Kroeber (1939, p. 42) states that the culture is characterized by "a religion which largely suppressed visible ritual and symbolism and substituted emphasis on song acquired by quasi-shamanistic dreaming, or pseudo-dreaming, within a highly conventionalized mythological pattern." When one asks a Mohave about almost any aspect of his culture, he says, "First you must understand how it happened in the beginning", and then he tells the origin myth with special emphasis upon the subject of inquiry.

Very briefly, the origin myth describes the way in which the Great Spirit, *matavily*, created the land and the people, who were identical with animals in the early history of the world. The first death and the first cremation occurred when the creator was bewitched by his daughter. Then *mastamxo*, the son of the Great Spirit, assumed leadership. He created the river and the plants for the people to use. Later he outlined the social organization of the tribe, giving certain powers to certain people—some were to be shamans, some warriors, some scalpers, and so on for all the statuses. When he had finished his work, he said, "This is all

[1]This article is a result of field work carried out with the assistance of a Demobilization Award from the Social Science Research Council during 1946–47.

yours and it will always be yours as long as you are dreamers." *Mastamxo* then changed his name, went downstream, and transformed himself into a fish hawk.

The origin myth clearly is an expression of the basic philosophical premises of Mohave culture. It is a fatalistic belief that all behavior is determined by the patterns established by the creators. The emphasis upon dreaming is very strong, running through almost all aspects of Mohave life. All power is received by dreaming, and it is the identical power which was given by *mastamxo* in the beginning. This results in a static conception of the universe. In each generation certain individuals automatically occupy the statuses which make up the social structure, but the structure itself remains unchanged forever. A belief in this mythology is one of the important sources of tribal morale.

All of the important officials of the tribe are sacred specialists in the sense that they derive their power directly from the creators by means of dream experiences. The major statuses recognized are shaman, of which there are several specialized varieties, scalper, custodian of the scalps, war chief, counsellor, and chief. The latter is a status which probably appeared after white contact. The shamans are concerned with sickness, both as witches who produce illness and as curers. A shaman first experiences a power-dream while in the foetal stage. These dreams are considered to be important determinants of personality, and the parents and relatives watch the behavior of the child from birth in order to detect clues to his future temperament or occupation. During infancy and childhood power-dreams recur but they are not remembered until late adolescence. A shaman does not start to practice until adulthood when he demonstrates his power by causing a close relative to become ill. Then later he attempts to cure the first occurrence of the disease over which he has power, thus insuring final public recognition of his status.

Shamans frequently cause their loved ones to die by means of witchcraft. The reason for this unusual behavior is that those people bewitched by a shaman form his "flock" in the afterworld. When they die such people are segregated in a particular place in the afterworld to await the coming of their bewitcher. However, people undergo several metamorphoses in the afterworld, eventually winding up as charcoal on the desert. If the shaman lives too long the people he has bewitched may move on to another stage before he can join them. This appears to explain the fact that shamans frequently make no effort to conceal their witchcraft, boasting of their deeds to the relatives of their victims. These relatives sometimes attempt to kill the shaman, especially in epidemics, and he makes no attempt to flee even if warned. This attitude of indifference to death is probably related to the fact that a shaman cannot wait too long to die if he wishes to join his flock in the afterworld.

The war chiefs and counsellors also experience power-dreams during infancy and childhood, but they are not revealed until the time to assume their positions in late adolescence or adulthood. These functionaries are largely secular specialists although they receive their power from the creators through dreaming. The same pattern applies to the chief, although there is a hereditary element in this status.

The *axwe satumac* performs several functions, only one of which, scalper, is used as the English label for this status. This person is a specialized shaman. He is a major functionary in the mourning ceremony which is one of the main Mohave rituals. This ceremony consists chiefly of a ritual enactment of warfare held in honor of several dead warriors. The scalper, who directs the mourning ceremony, also goes on war expeditions. During the battle he removes the scalps of fallen enemies and takes charge of female prisoners if any are captured. While the expedition is homeward bound, the scalper "tames" the scalps and kneads them to make them pliable.

The function of the scalper in connection with warfare, the mourning ceremony, and the welfare of the tribe makes him an important religious official. The crux

of his position is his power over the "enemy sickness." The Mohave believe that contact with people outside of the tribe is dangerous since it may produce this disease. This danger pervades the scalps of slain enemies before they are tamed by the scalper, as well as the captive females brought back by a war party. It is a danger in any intimate contact such as sexual intercourse or eating with anyone outside the tribe. The scalper, being a shaman, has power over this disease and can cure people afflicted with it. The scalps, as will be described later, bring beneficial power to the tribe after they have been tamed. The scalper, then, contributes to tribal welfare by his power to tame the scalps and to cure the "enemy sickness." He also directs one of the most important Mohave ceremonies. Scalper is one of the most important religious statuses, but not the most important one because of the ambivalent attitude of the tribe resulting from the fact that the scalper is also a shaman, which means that he can practice witchcraft.

The concept of "enemy sickness" reveals much about Mohave feelings of tribal solidarity. Their beliefs concerning tribal affiliation express a kind of "racist" philosophy. All members of the tribe are "one folk" connected with the creators by biological descent. Purity of the blood has always been a primary consideration. They have an intense interest in "increasing the tribe" which is a manifestation of the desire to perpetuate the biological bonds with the creators and to insure the continued existence of a desirable way of life. The "enemy sickness" is phrased in physiological terms. As Devereux says (1935, p. 81), "The Mohave assume that every other tribe or race has a stronger blood than their own . . . ." and that any intimate contact will produce the dreaded disease.

When the scalper returns with the war party he turns the scalps over to the *kwaxot*, or custodian of the scalps, who is the principal Mohave religious leader. The custodian of the scalps prepares a great celebration in honor of the returning warriors. The people come from all over the valley for the singing, dancing, feasting, and ritual that mark the return of a war party. The custodian places the scalps on a pole which is given to a woman who dances with them. At certain junctures in the dancing the scalps are raised high in the air and all the people shout and throw dust upon them. During the feasting some of the corn and beans is thrown to the scalps. After the feast the custodian of the scalps places them in large pottery ollas for safekeeping.

The custodian of the scalps then addresses the throng, urging the young people to marry and have "lots of children so that the tribe will grow." He urges them to enjoy themselves sexually, which they have been doing since the first day of the ceremony and which they continue doing until the people return to their homes. During the victory celebration a family with a virgin daughter—virginity is rare even among very young girls—offers her to a young man who has achieved prestige by killing his first enemy. The female captives are given by the custodian of the scalps to some of the old men who need wives. Young men are afraid to take these women because of the "enemy sickness" but the old men are glad to have them since they have lived a long time and do not have long to live under any circumstances. The scalp ceremony, with the custodian of the scalps as the chief functionary, represents a close connection between patterns of warfare, religion, and tribal fertility and continuity. The custodian keeps the scalps, examining them periodically and washing their hair with mud when necessary. Each time they are washed the whole tribe gathers for a celebration similar to the one just described. These affairs serve to bring the people together and to reinforce their sense of tribal unity. The scalps are dramatic symbols of tribal power and their treatment and display calls forth a high degree of social euphoria. The young people are expected to establish sexual relationships at these events, and the custodian of the scalps constantly encourages them to increase the tribe by having children and lectures to them about marriage and their duties to the tribe. The symbolism of the scalps is not as yet completely clear. They apparently bring good luck and

power to the younger generation and seem to be connected with increase of the tribe. It is apparent that they are awesome symbols of tribal power and that the status of custodian of the scalps, the chief religious office, forms the nexus of two great themes of Mohave life, warfare and tribal fertility.

The occupants of the statuses described above are the people who have experienced major power-dreams. A number of men may simultaneously fill the position of shaman, counsellor, and war chief, but there is only one scalper and one custodian of the scalps in the entire valley. The occupants of these major statuses do not actively seek their power, as evidenced by the fact that some of the dreams occur prior to or immediately after birth. There is no idea that power can be achieved by asking for it or earning it or torturing oneself for it—it comes automatically to certain people. Almost all the members of the tribe have some minor-power dreams designed to give facility in agriculture or fishing or hunting, but these are in the nature of good luck dreams, and are not as specific as the major power-dreams. Mohave religion, as distinguished from most religions, does not contain rituals designed to increase the crops or insure the adequate flooding of the river. No attempt is made to enhance the food supply by religious or magical means. This fact may be connected with the relative adequacy of the food supply mentioned earlier.

The relationship of Mohave mythology and religion to tribal organization and morale may be summarized as follows: The origin myth defines the social structure of the tribe. The people are related to the creators by direct biological descent. They are also part of the tribe by virtue of their need for the services of certain people occupying the statuses originated by the creators. According to Mohave premises the individuals who fill these major statuses are indispensable to the welfare of the tribe as a whole. Through the occupants of these statuses the Mohave come into contact with the sacred in terms of a nationalistic religion. The Gods are tribal Gods, and the specialists are tribal representatives. If they do not dream, the duties which *mastamxo* prescribed cannot be carried out and the tribe is unable to function adequately. The people are dependent upon the individuals who have the power to fill the essential statuses. The average Mohave does not request the aid of the supernatural, nor does he give thanks for his success and happiness. There is no direct personal relationship with the supernatural for the average Mohave, but he is in contact with the sacred by virtue of his membership in the tribe. The tribal officials do those things which are essential for the welfare of all, thus forming, through their unsought dreams, a link with the creators. This relationship is explicitly recognized by informants who say that the "common people," meaning those who do not have important power-dreams, "do not try to do anything, but just depend on those who have good dreams." Religion and mythology, therefore, clearly reinforce the strong sense of tribal unity characteristic of the Mohave by channeling supernatural contacts through a series of indispensable tribal officials who automatically receive the power necessary for the existence of the people.

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THE ROLE OF CERTAIN ARTHROPODS IN REDUCING MOSQUITO POPULATIONS OF PERMANENT PONDS IN OHIO

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An examination of the literature shows that transient rather than permanent bodies of water are most favorable to the production of mosquitoes, and further that there is little data explaining why this is so. Part of the answer may lie in (1) the fact that the mosquito fauna of permanent ponds is different from that of temporary ponds and pools, although Mead (1949) has shown that species such as *Anopheles quadrimaculatus*, *Aedes vexans*, and *Culex pipiens* breed in both types of habitat, and (2) the fact that there is higher mortality among the larvae in permanent ponds.

The predatory activity of the arthropod fauna doubtless causes much of this larval mortality. However, most general works dealing with mosquitoes only briefly discuss arthropod predation and thus leave the impression that it is unimportant. Arthropods other than insects have seldom aroused the interest of investigators, and relationships other than predation have been given little consideration.

The writer has conducted an inquiry into these problems and here reports some observations which he made concerning predation and competition in permanent ponds. The work was carried out during the summers of 1947 and 1948, and the principal facility used was the Ohio State University farm pond. This pond was inspected several times each week. Supplementary aquarium studies were carried on concurrently. In addition, a number of other ponds and pools were observed at irregular intervals for the purpose of making comparisons.

LIMITS TO POPULATIONS OF MOSQUITO LARVAE

Many insects and some other arthropods prey upon mosquito larvae. Furthermore, the arthropods can limit mosquito breeding in other ways. Thus a large reservoir of predators is supported by the herbivores, such as mayflies and midges, which are present throughout the year. Whenever mosquito larvae are introduced into the pond, predators are already present and will begin to take a toll. Since the midges and other herbivores provide a series of alternate hosts for the predators, the mosquito population will not build up ahead of a lagging predator increase.

Secondly, the arthropods compete with the mosquito larvae for the available food. Little is known about this competition. Weed (1924) made a very brief report of a pond in which he thought cladocerans completely prevented mosquito breeding by utilizing all of the food.

Finally, the larger arthropods can create an unfavorable physical environment for mosquito larvae by their movements. This is because the larvae and pupae of many mosquito species move rapidly when they are disturbed and constant escape reactions can slow down their development and expose them to predation. When *Aedes aegypti* larvae were kept in an aquarium with hydrophilid adults, many of them died because the beetles were constantly moving. Such mortality doubtless rarely if ever occurs naturally. In ponds hydrophilid adults spend most of the time feeding and resting on the bottom with occasional trips to the surface where they obtain air. Since there are several beetles per lineal foot of shore in the Ohio University pond in July, they would continuously disturb any immature mosquitos in the vicinity. The constant motions of notonectids and gyrinids would also produce a pronounced disturbance of larvae in their paths.

SOME IMPORTANT PREDATORS: COPEPODS AND INSECTS

Haub (1930) in a review of the literature does not mention copepods. The present author has not discovered any report of their predacious activity since that time. However, some species of these microcrustaceans readily feed upon first and second instar mosquito larvae when they are kept in aquaria.

Several species of *Cyclops* are common inhabitants of shore water and the water among the plants in ponds and lakes. Mosquito larvae probably occur in their normal diet. Members of the genus can capture moving larvae and retain a grasp throughout vigorous movements of the prey even though this prey is often larger than the captor. These copepods attack both culicine and anopheline type larvae, but they capture culicines much more often.

During 1948 a group of *Cyclops* was kept in a small dish and provided daily with *Aedes aegypti* larvae. The copepods seized the larvae seconds after they were added. Individual copepods consumed about five first and second larvae per day. *Aedes aegypti* larvae placed in a large aquarium with a mixed population of small invertebrates, including copepods, disappeared, and they were probably taken by the *Cyclops* which were the only predacious metazoan species present.

The relatively large aquatic insect predators of many species probably consume many more larvae than do the copepods. Odonatan nymphs are among the most numerous predators in many ponds and the habits of a number of species are such that they would encounter mosquito larvae. For instance, damselfly nymphs cling to stems along which mosquito larvae feed. The long-legged nymphs of the dragonfly *Erythemis simplicicolis* wander about in the vegetation and in the little pools within the surface blanket of algae. Bottom dwelling forms such as *Libellula* spp. probably move to shallow water at night, as they are sometimes seen moving back to central parts of the pond from the shore between midmorning and noon.

Other insects including notonectids, dytiscid larvae and adults, naucorids, hydrometrids, some neuropterons, and hydrophilid larvae prey on immature mosquitos. On the average, according to aquarium studies made by the author, a centimeter long insect predator can destroy ten third and fourth instar mosquito larvae per day. A large anisopteran nymph will consume as many as one hundred large larvae in a day.

The larvae of hydrophilid beetles of the genus *Tropisternus* are especially important predators. Hixson (1943) presented data indicating that in Florida larvae of *Tropisternus* spp. were the principal predators of anopheline larvae in an association in which no minnows were present.

The present author found that *Tropisternus* larvae have structures and feeding habits which make them efficient in destroying mosquito pupae. These beetle larvae obtain air through posterior spiracles which are kept in contact with the water surface. Therefore they walk about on vegetation or along the shore where the water is a half inch or so deep in places where mosquito pupae tend to collect. Furthermore, the hydrophilid larvae move continuously and they will leave the water and travel overland and possibly reach small isolated puddles containing mosquito larvae.

When *Tropisternus* larvae ingest food they hold the head out of the water and spend considerable time macerating their prey. This manner of eating further confines them to the top half inch of water.

These beetle larvae when kept in an aquarium captured mosquito pupae easily, but they had difficulty in catching the larvae. Field observations of feeding were difficult to make. In one instance a beetle larva and a mosquito pupa were dipped together from a ditch. The larva immediately captured the pupa. A farm water tank examined in late August contained anopheline larvae and hydrophilid larvae and numerous smaller invertebrates. No mosquito pupae were present so it is probable that the hydrophilids were destroying them as they formed.

THE IMPORTANCE OF ARTHROPOD PREDATION

Arthropod predators are abundant and have a great diversity of structure and habit. Throughout the year various species inhabit open water and vegetated areas, shore and bottom areas, and regions of low and high oxygen concentration. The soft-bodied mosquito larvae which swim conspicuously and which spend a pupal period exposed at the water surface, would seem to be susceptible to these predators.

These predators, therefore, very likely help prevent a large production of mosquitoes in permanent bodies of water. This is indirectly indicated by Herms, Hackett, and others who list ecological provinces in order of importance of mosquito production as: (1) floodwater remnants, (2) artificial containers, (3) woodland pools, (4) swamp-ponds, and (5) streams and ditches.

This is roughly in inverse order to habitats listed according to the abundance of predacious arthropods. Similarly, Mead (1949) states that the worst pests in central Ohio are temporary pool breaders such as *Aedes vexans* (Meigen), *A. stimulans* (Walker), *A. trivittatus* (Coquillet), and species of *Culex* and *Psorophora*.

A survey in the Columbus area will disclose small temporary pools of water with a surface area of a few square feet which contain more mosquito larvae than large permanent ponds. Mead's records of mosquito larvae in the University pond show *Anopheles quadrimaculatus* larvae or pupae present on August 1, 8, and 25, and Sept. 21, 1948. But on the 25th of August, even though a dense algal mat was present, there was only a total of 17 larvae and two pupae in 75 dips. These low pond populations are probably often the result of the rich insect and copepod fauna present.

SUMMARY

Arthropods prey upon mosquito larvae and maintain reservoirs of predators. They compete with mosquito larvae for food and space.

Copepods of the genus *Cyclops*, which are abundant in quiet water, feed upon first and second instar larvae of mosquitoes. Hydrophilid larvae of the genus *Tropisternus* have habits which make them important mosquito pupal predators.

Permanent ponds produce fewer mosquitoes than do transient ponds and pools. Arthropod predation is probably an important cause of mosquito larval mortality in permanent ponds.

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Entomology for Introductory Courses. *Robert Matheson.* Comstock Publishing Company, Ithaca, N. Y. Second Edition, 1951. xiv+629 pp. $6.00.

The second edition of this outstanding book for introductory courses in entomology is most welcome. It embodies the same general features as the first edition with the following changes: enlargement of many former illustrations, especially in the chapters on morphology and mouthparts, and the addition of several new ones; some of the keys have been revised and improved so they are more useful and workable, as well as the introduction of more key character illustrations; page references assist in finding detailed information more readily. The book stresses the biological phases of insects and the important part which they play in world societies.

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